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ACQUIRING MAJOR SYSTEMS: COST AND SCHEDULE TRENDS AND ACQUISITION INITIATIVE EFFECTIVENESS

Karen W. Tyson, *Project Leader*
J. Richard Nelson
Neang I. Om
Paul R. Palmer

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INSTITUTE FOR DEFENSE ANALYSES
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This paper examines trends in the outcomes (in terms of costs and schedules) of major weapon system acquisition programs and assesses the effectiveness of management initiatives in improving these outcomes. Program outcomes are assessed by equipment type (including aircraft, tactical munitions, electronics, stratetic missiles, and satellites), by time period, by phase (development and production), and by type (new or modification). The major drivers of total program cost growth are also examined. The initiatives assessed include multi-year procurement, prototyping, total package procurement and fixed-price development, dual-source competition, design-to-cost, and contract incentives.

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PREFACE

This paper was prepared by the Institute for Defense Analyses (IDA) for the Office of the Under Secretary of Defense (Acquisition), under contract MDA 903 84 C 0031, Task Order T-G7-416, issued 30 June 1987, and amendments. The objective of the study was to present trends in costs and schedules for major system acquisition programs and to assess the effectiveness of six acquisition initiatives in influencing costs and schedules.

This paper was reviewed within IDA by Mr. Stanley A. Horowitz and Dr. David R. Graham, and by Dr. Alexander H. Flax, an IDA consultant.

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The organizations that contributed information to the study include:

- Office of the Secretary of Defense
- U.S. Army
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- U.S. Navy
- The Boeing Company
- General Dynamics Corporation
- General Electric Company
- Grumman Aerospace Corporation
- Hughes Aircraft Company
- Martin Marietta Corporation
- McDonnell Douglas Corporation
- Raytheon Company
- Rockwell International Corporation
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Ms. Janet Jones-Brooks provided capable secretarial support to the study and prepared the manuscript. Ms. Linda Garlet edited the document for publication.

EXECUTIVE SUMMARY

The purpose of this study was to examine trends in the outcomes (in terms of costs and schedules) of major system acquisition programs and to determine the effectiveness of management initiatives in improving these outcomes. IDA examined cost growth by equipment type (including aircraft, tactical munitions, electronics, strategic missiles, and satellites) by time periods, by phase (development and production), and by development type (new or modification). The initiatives assessed were:

- Multi-year procurement
- Competition
- Prototyping
- Design-to-cost
- Total package procurement and fixed-price development
- Contract incentives.

Three important issues were addressed:

- Have defense system program outcomes improved over time?
- Have acquisition initiatives been effective in improving defense system program outcomes?
- What recommendations for improving defense systems program outcomes can be made ?

A. APPROACH

Our approach to this study is described below:

- Develop a framework for analysis by reviewing reports of defense commissions and panels and by developing a taxonomy of acquisition strategy initiatives.
- Develop cost and schedule histories of selected programs using Selected Acquisition Report (SAR) data, Development Concept Paper (DCP) information, and other information from the military services, program offices, and the defense industry.

- Identify and categorize the significant issues of the programs selected.
- Assess quantitatively the effectiveness of initiatives in controlling or reducing costs, both at a macro-level (across all programs) and at a micro-level (on the basis of individual case studies).
- Identify the most effective initiatives and provide recommendations.

IDA collected information on 89 SAR programs. Programs with recent starts were excluded, leaving development information on 82 programs and production information on 73 programs. Outcome measures included development cost, schedule, and quantity growth; production cost, schedule, and quantity growth; and total program cost growth. Growth was defined as actual cost relative to cost estimated at Milestone II full scale development (FSD) start.

To augment the database and to get additional insight into program management issues, IDA compiled case studies on several programs that had used initiatives relevant to the study.

B. FINDINGS

Have defense system program outcomes improved over time? Our work has indicated that:

- Program cost trends have neither been getting uniformly better nor uniformly worse over time. If the data are organized by FSD start date, total program cost growth was higher during the late 1960s, lower in the early 1970s, and higher in the late 1970s. For the 1980s, only five programs met our criteria for inclusion, and even these are in the early stages of production. We cannot draw firm conclusions on 1980s programs, since cost growth tends to accumulate as programs mature.
- Tactical munitions had the highest total program cost growth--2.07 vs. an average for other types of 1.31. Experiences with equipment types other than tactical munitions were generally much better.
- For the most part, as might be expected, modification programs experience less cost growth than new starts, except in the cases of tactical munitions and electronic aircraft. Tactical munitions have a higher percentage of technological content than other weapons systems. These systems are usually not the highest priority in the services and therefore may not receive as much attention from high-level management as needed. Costs for tactical munitions modifications are usually underestimated, because a modification often

comprises a new guidance and control system, the largest and most difficult to estimate part of the equipment cost.

- Development cost growth in avionics was the highest of any equipment type--1.75 for avionics vs. an overall average of 1.27. (We could not evaluate production cost growth for avionics, because these costs are usually contained in platform SARs.) The fact that many avionics programs are being planned suggests that these programs will be a problem area in the future.
- Development schedule growth, production stretch, and development schedule length are the major drivers of total program cost growth. Production stretch in particular has increased cost growth by 7 to 10 percentage points per unit increase in stretch (for example, by doubling the production schedule length while keeping quantity constant).

Have certain acquisition initiatives been effective in improving defense system programs outcomes over the years? Some initiatives have performed better than others:

- Multi-year procurement (MYP) has been successful under the guidelines used by DoD and Congress to determine candidate programs. Cost growth has been lower in MYP programs than in the general population of programs. The average production cost growth for MYP satellites was 1.15; for other MYP programs it was 1.31. This compares to an average of 1.75 for non-MYP programs. This is in part because these programs had to be fairly stable to be accepted for MYP. However, a comparison of MYP programs with rejected MYP candidates indicates that MYP has had some beneficial effects, even given program stability.
- Dual sourcing (competition) in major weapons systems has had mixed success. We have seen examples of both good and bad applications. Guidelines are needed for the use of dual sourcing.
- Prototyping, the construction and testing of working models before FSD, has generally been successful. Prototyping yields information to reduce uncertainties and to preclude unattractive options. While prototyping involves extra costs early in the program, some evidence indicates that part of the extra time and resources are recovered in FSD and that prototyping holds down development and production cost growth.
- Design-to-cost has not been successful because it has been applied during FSD, too late in the program to be effective. Design-to-cost has been used as a monitoring device rather than as a design tool. However, in the late 1970s, when design-to-cost had time to develop as an initiative, there are indications that it was more successful.

- Both fixed-price development and total package procurement have been unsuccessful when used for high-value, high-cost, high-risk, long-term programs.
- Contract incentives in FSD are associated with lower development cost growth for some equipment types. For strategic missiles and satellites, contract incentives in FSD and in production are associated with lower total program cost growth.

C. RECOMMENDATIONS

What recommendations for improving defense system program outcomes can be made?

- Provide stable budgets and take action to avoid production stretchouts.
- Give tactical munitions and electronics/avionics programs increased management attention.
- Develop guidelines for correctly applying initiatives to programs.
- Continue strict guidelines for selecting programs for MYP. (Congress accepts one-third to one-half of the MYP candidates.) Consider expanding the pool of MYP candidates if higher savings are desired and if more risk is acceptable.
- Be selective in the use of competition. Develop guidelines for competition, including requiring a break-even analysis. Benefits other than cost savings (such as contractor responsiveness and system reliability) and the industrial base need to be considered.
- Apply prototyping during advanced development (for systems and critical subsystems) in cases where significant information is to be gained and where the prototype represents only a small percentage of acquisition cost.
- Use design-to-cost early (in concept exploration and demonstration/validation) when design tradeoffs are still feasible.
- Do not implement fixed-price development or total package procurement in high-risk, long-term programs.
- Use a mix of incentive fees and award fees in development and in early production. Use firm-fixed-price contracts in later production.
- Examine cross-program effects and industry strategies to understand how they affect program outcomes.

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I. INTRODUCTION

A. PROBLEM AND BACKGROUND

The Department of Defense (DoD) has a responsibility to make the best use of limited resources for defense. At the same time, keeping pace with the changing threat often requires weapon systems that are at the leading edge of the state of the art in a variety of technologies. Cost overruns, particularly for high-technology programs, have reached public visibility with increasing frequency. Costs are perceived to be higher than reasonably expected.

As a result, congressional scrutiny of the defense budget has increased, and blue ribbon panels to recommend ways to improve the acquisition process have been established. By subjecting past and present acquisition policy and practice to rigorous scrutiny, DoD might better identify effective initiatives for application to future system acquisitions, and thereby address concerns over future limitations of resources.

The defense acquisition process has become increasingly complex over the years. Layers of management, regulations, and approval processes have been imposed on the system. Systems of fiscal control and reporting have been established. Has this complexity brought about positive change? Are acquisition program costs and schedules better now than in the past? What are the causes of cost and schedule problems? What actions by DoD (e.g., specific acquisition strategies and management initiatives) have improved costs and schedules? Finally, what can be done to improve defense system program outcomes? These are some of the issues this paper explores.

B. OBJECTIVES

To answer these questions, we developed the following objectives:

- Present trends of cost and schedule expectations and outcomes for a large group of major programs.
- Choose a set of specific acquisition initiatives or strategies for study and describe the impact of these on cost and schedule expectations and outcomes.
- Assess the effectiveness of initiatives and provide recommendations.

C. APPROACH

The approach we took to attain those objectives included the following tasks:

- Development of a framework for analysis. In addition, we developed a taxonomy of acquisition initiatives and chose those most appropriate for the study. We reviewed the reports of commissions and panels that focused on acquisitions reform. We also selected a group of programs for the analysis.
- Collection of Data. Cost and schedule histories of a large group of major programs were collected, principally using Selected Acquisition Reports (SARs). We supplemented this information with Secretary of Defense Decision Memoranda (SDDMs), Development Concept Papers (DCPs), and other data. In addition, we received government and industry support for selected case studies.
- Examination of case studies. In order to enrich our understanding of the implementation of the initiatives and of issues and outcomes not found in the database, we looked at a number of specific cases in more detail. This involved additional data collection, discussions with representatives of the program office and of industry, and review of relevant literature. Supporting organizations included the Office of the Secretary of Defense (OSD), the Army, the Navy, the Air Force, and ten major contractors.
- Analysis of trends in cost and schedule outcomes.
- Assessment of the effectiveness of acquisition initiatives in minimizing cost and schedule growth.

D. A NOTE ON SCOPE

In defining program outcomes for the study, we focused on cost and schedule outcomes rather than on performance. Clearly, the ultimate test of a system is its performance in the field; however, building a database of the performance of fielded systems is difficult. Another possibility we did not pursue was to measure the degree to which systems met their performance goals. We found that systems generally met essential performance goals, but that cost and schedule goals are more problematic for government and contractors. The impact of excessive or unobtainable performance requirements on sy tem costs can be important, but this issue was beyond the scope of this study.

E. OUTLINE OF REPORT

Section II gives an overview of defense acquisition policy over the years. In Section III, the acquisition program data used in the study is described. Section IV discusses trends in acquisition program cost and schedule outcomes, and Section V discusses factors that might account for differences in cost growth. Sections VI through XI discuss the acquisition initiatives as follows:

- Section VI, multi-year procurement
- Section VII, competition
- Section VIII, prototyping
- Section IX, design-to-cost
- Section X, total package procurement and firm-fixed-price development
- Section XI, contract incentives.

Section XII presents conclusions and offers recommendations.

II. BACKGROUND AND ISSUES

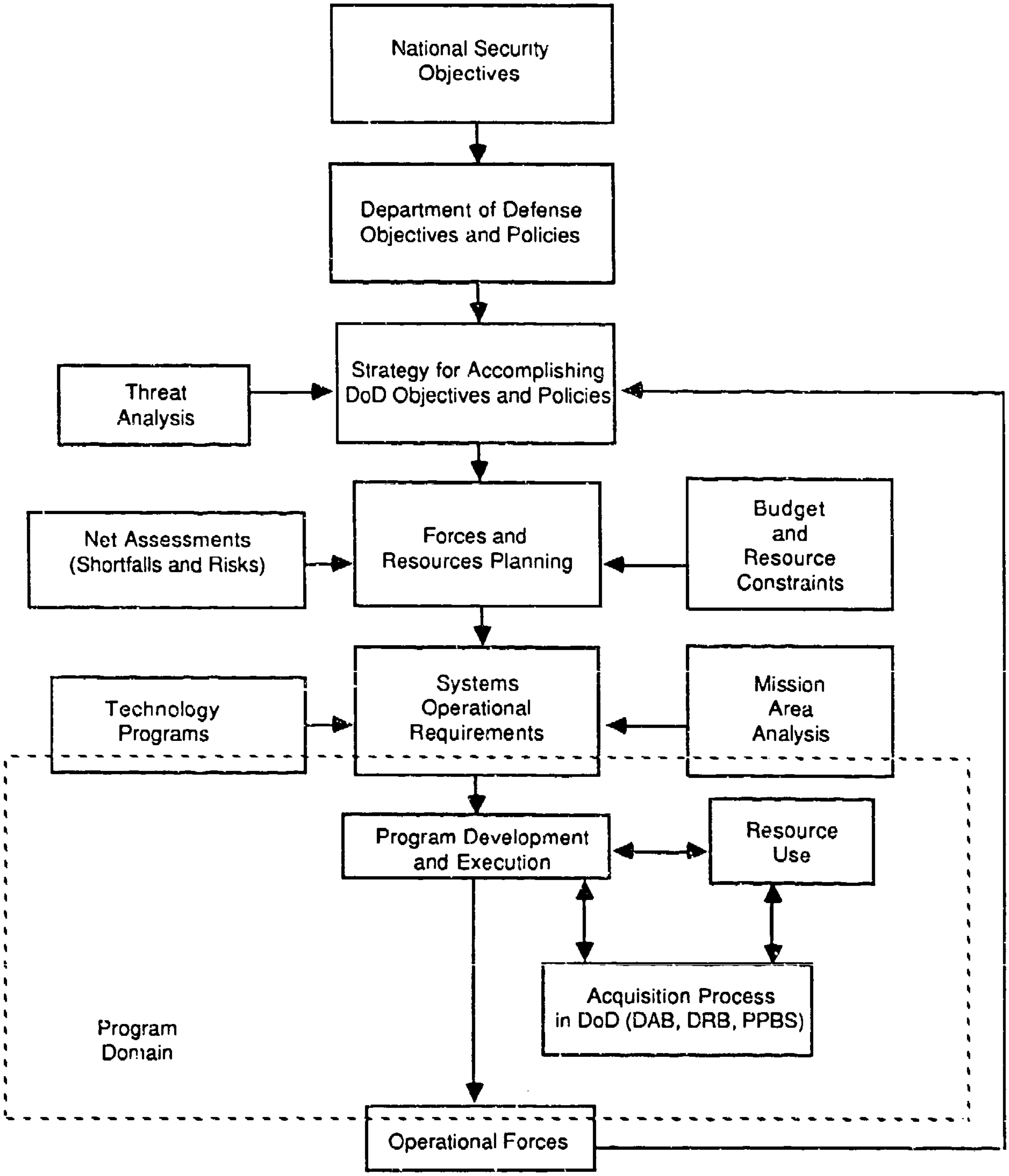
A. THE DEFENSE ACQUISITION PROCESS

Systems acquisition is the development and procurement of weapon systems for national defense. A weapon system is defined as a collection of integrated components to achieve a specific purpose. Acquisition may involve, as it did early in the post-World War II period, the selection of a production model from several prototypes and purchase of off-the-shelf articles, or it may involve a long process of development before production. Development includes early conceptual and validation efforts as well as full scale development. Today, development can take 6-10 years, depending on the type of equipment, difficulty of the requirement, and maturity of the technology.

This section describes an abstract analytical structure for the acquisition process. It presents our view of how decisionmakers would approach defense acquisition in the absence of political constraints.

An overview of the national strategic planning process is presented in Figure II-1. It is an *analytical* strategic planning model in that it flows sequentially and does not indicate how political and organizational behavior may influence decisions at various levels. Typically, the President establishes foreign and domestic policies. He receives advice from the National Security Council, the Secretary of State, the Secretary of Defense, the Joint Chiefs of Staff, members of Congress, and other personal advisors. Specific objectives and policies can range from maintaining alliances throughout the world, defending U.S. interests in strategic areas, and maintaining nuclear deterrence to advancing new technologies, ensuring an adequate industrial base for defense, and ensuring the economic viability of allies.

Based on administration policies, the DoD develops its method for accomplishing national security policy objectives. DoD assesses the capabilities of existing forces and the resources available for defense. From this information, it develops operational requirements and translates those requirements into operating forces. The output of this



Source: Reference [II-1].

Figure II-1. Overview of National Security Strategic Planning

process is a set of operational requirements for expansion, modernization, and support of military forces. These requirements are translated into systems that are defined, developed, and acquired through a military service or agency program following an acquisition strategy.

Program offices are established to refine program requirements, to develop and acquire these systems, and to integrate them into operational forces. Military service or agency program managers preside over the execution of the process within DoD. They are responsible for interaction with their superiors and with the Defense Acquisition Board (DAB), the Planning, Programming, and Budgeting System (PPBS), and the Defense Resources Board (DRB). The programs are monitored by OSD and military service management.

B. ERAS IN DEFENSE ACQUISITION

In this study, we want to determine whether outcomes are getting better or whether cost growth, in particular, is a persistent problem. We discuss four different time periods: the 1960s, the early 1970s, the late 1970s, and the 1980s. These represent different eras in defense acquisition. Nelson and Tyson [II-2][1] give a fuller historical perspective of defense acquisition.

During the 1960s, Secretary of Defense Robert McNamara introduced mechanisms for planning defense acquisition. He initiated the PPBS and the Five-Year Defense Plan (FYDP). Systems analysis was a method of using paper studies and simulations to choose among alternative technologies. Management was centralized within OSD. Concurrency in development and production was often used in an effort to speed the process. The presumption was that properly planned programs would proceed smoothly. After 1965, the total package procurement concept was used in an effort to reduce the government's cost risks. The Selected Acquisition Reporting (SAR) system was introduced in 1968 to summarize cost, schedule, and performance data on major systems.

During the early 1970s, there was a negative reaction to this philosophy. A number of total package programs had large cost overruns, and contractors had to be bailed out. Total package procurement was discontinued in favor of cost-plus-incentive-fee contracts. Deputy Secretary of Defense David Packard urged doing away with concurrency and using

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1 In this paper, references, found at the end of each section, are referred to by number in brackets.

a more cautious, phased process under which programs had to pass "milestone" tests before they could move on to the next phase. Prototyping, testing using actual hardware rather than paper studies, became more prevalent. More responsibility for day-to-day management of programs was delegated to professional program managers. More controls related to cost monitoring were imposed. The Cost Analysis Improvement Group was set up. DoD instituted the design-to-cost initiative to encourage knowledgeable cost-performance tradeoffs in acquisition.

During the late 1970s, several major programs started. Concern grew about the impact of prototyping and milestones on acquisition intervals and about the timely fielding of systems. Some observers have pointed to 1974 as a watershed year for increased congressional management of the acquisition process. In addition, there was growing concern about resource constraints; extremely high inflation meant that budgets intended to cover reasonable price increases ended up buying considerably less than expected. Program stretchouts became a common practice. Rather than canceling programs for which substantial investments had been made in development, Congress either stretched production, thus increasing unit costs, or made supplemental appropriations.

During the 1980s, a major buildup in acquisition began and many new starts were designed to exploit new technologies rapidly. The Acquisition Improvement Program (the so-called Carlucci initiatives after Deputy Secretary of Defense, Frank C. Carlucci) was a 31-point plan to improve the acquisition process. These points can be grouped into five areas: improve general management principles, increase program stability, improve forecasting and information, improve support and readiness, and reduce bureaucracy. Congress later added a 32nd initiative calling for increased competition. Dual sourcing of major systems and subsystems was encouraged and greater emphasis was placed on operational test and evaluation. Two conflicting concerns gained prominence in the 1980s--a sense that fraud, waste, and abuse needed to be attacked with additional auditing and regulation, along with the concern that the regulatory and administrative burden on contractors was contributing to high costs.

C. RECOMMENDATIONS FOR REFORM

Since the beginning of DoD, many studies have been done by panels, commissions, and other bodies on how major systems ought to be acquired and on related issues such as the organization of the DoD. These bodies can play several different roles. They can be catalysts for change. For example, the 1972 Commission on Government

Procurement resulted in the development of Circular A-109, which codified acquisition policy for the entire federal government. Panels and commissions can also ratify change that has already happened. For example, the 1970 Fitzhugh Commission recommended that there be no more total package procurement, when, in fact, the government had already decided against it. They can also be used to enhance the visibility of change that has already occurred. Finally, they can be an important safety valve. When officials want to appear to be responsive to a problem, they appoint a commission to study it. As part of our research, we reviewed the recommendations of as many of these commissions, panels, and studies as we could find. We also used a summary of the recommendations of 25 of the most important studies [II-3]. The eight major bodies we examined are:

- The First Hoover Commission, 1949 [II-4]
- The Rockefeller Commission, 1953 [II-5]
- The Second Hoover Commission, 1955 [II-6]
- The Blue Ribbon Defense Panel (the Fitzhugh Commission), 1970 [II-7]
- The Commission of Government Procurement, 1972 [II-8]
- The Defense Resource Management Study, 1979 [II-9]
- The Grace Commission (President's Private Sector Survey on Cost Control), 1984 [II-10]
- The Packard Commission (Blue Ribbon Commission on Defense Management), 1986 [II-11].

The principal issues studied by the panels included:

- Organizational responsibility for acquisition within DoD
- Acquisition strategies and techniques.

A common feature of commissions and panels is the tendency to identify a particular problem and then recommend an office be established to oversee or solve it. Thus, organizational responsibility for acquisition has changed over the years.

Some recommendations come up repeatedly. For example:

- Multi-year contracting was recommended by five different groups (the Symington report of 1960 [II-12], the Office of Federal Procurement Policy (OFPP) study of 1982 [II-13], the DSB study of 1983 [II-14], the Grace Commission of 1984 [II-10], and the Packard Commission [II-11]).
- Limiting the number of programs to those that can be funded was recommended by four panels (the Acquisition Advisory Group in 1975 [II-15],

the Acquisition Cycle Task Force in 1978 [II-16], the Affordable Acquisition Approach study in 1983 [II-17], and the Grace Commission in 1984 [II-10]).

- Simplification of the process was a common theme in many recommendations (the Grace Commission recommended that contract clauses, the regulatory system, specifications, and contracting in general be simplified; the OFPP study in 1982 recommended that simplified procedures for commercial procurement be developed and that procedures for small purchases be simplified; and the Acquisition Cycle Task Force in 1978 recommended shortening the front end of the acquisition cycle).
- Four separate studies recommended that a positive career path be established for program managers (the Fitzhugh Commission in 1970 [II-17], the Rand study of the 1970s experience [II-18], the Defense Science Board in 1983 [II-14], and the Grace Commission in 1984).

On the other hand, some recommendations regarding acquisition strategy have varied. During the 1970s and 1980s, a flurry of recommendations were made promoting increased competition. Other recommendations include preplanned product improvement, better cost analysis and early warning systems for cost growth and schedule slippage, independent subsystem development, and improved planning tools. In addition, many recommendations have been made relating to overstated requirements, unnecessary regulations, improving technology, operational test and evaluation, unnecessary bureaucratic layers, program strategy, and resource planning.

The following summarizes recommendations with respect to the initiatives:

- MYP was recommended frequently, as previously discussed.
- Competition (dual sourcing) was recommended by the Grace Commission. Increased commercial-style competition was recommended by the Packard Commission. The Acquisition Cycle Task Force study [II-16] and Dews [II-18] called for considering competition in all phases of the acquisition cycles.
- Prototyping was one of the Packard initiatives and was recommended by the Packard Commission.
- Design-to-cost was a Packard initiative, but was not explicitly addressed by any of the groups.
- Total package procurement should be prohibited, according to the Fitzhugh Commission.
- Incentive contracting was not fully addressed by any of the groups.

D. TRENDS AND CYCLES IN DEFENSE SYSTEM ACQUISITION

Dramatic changes in the size of the DoD budget over the past four decades have fostered a feast-or-famine attitude about the availability of funds for research and development (R&D) and production in industry. However, successive "famine" periods are on higher plateaus in each successive cycle. There is also a "cushion" after an expansion period. When the government does cut total obligational authority (TOA), the defense industry does not feel the effects immediately, because contracts are still making outlays. The reverse is also true; expansion periods take some time to build up. Occasionally, programs are canceled, thereby canceling any unspent TOA. But most often in a constrained budget, procurement rates are reduced and program schedules are stretched so that funding is reduced, but not eliminated.

There have been three major cycles in DoD organization since World War II. These include:

- ***Centralization and decentralization of broad DoD decisionmaking.*** In both the Truman and Eisenhower administrations, the tendency was toward centralization of functions and away from the decisionmaking power of the services. These steps were cautious at first--in the Truman administration, the idea of having an umbrella organization over the services was new. During the Eisenhower administration, the Secretary of Defense got the power to hire and fire staff. The Kennedy-Johnson administration further consolidated power within the Secretary's office by introducing PPBS and systems analysis. Up to that point, overall DoD organization was following a trend toward centralization. During the Nixon and Ford administrations, some power was given back to the services. There was a move to push decision power further down the chain. The Carter administration moved back toward centralization. Then the Reagan administration moved to decentralize some authority.
- ***Centralization and decentralization of acquisition decisionmaking between OSD and the services and differentiation of the bureaucracy within OSD.*** Until the Eisenhower administration, the services basically did their own procurement. Then an acquisition bureaucracy at the OSD level began to evolve. Acquisition evolved from a simple buy/no buy decision to a two-phase process--development and production. The creation of the post of Director of Defense Research and Engineering (DDR&E) in 1959 resulted in further differentiation of the OSD bureaucracy. During the Nixon administration, Packard tried to bring parties together with the Defense Systems Acquisition Review Council (DSARC) process. The DDR&E gradually became stronger and gained status during the Carter administration by being upgraded to an under secretary (USDRE) and being

designated as the Defense Acquisition Executive (DAE). The Reagan administration broke up this package by strengthening the Acquisition and Logistics Office, which then vied with USDRE for status as the chief acquisition office--a dispute that was eventually settled when Deputy Secretary Taft assumed the role of DAE. The Packard Commission's recommendations included the establishment of an acquisition "czar" to oversee the entire process, an attempt to put everything back together again.

- ***The upgrading and downgrading of systems analysis since Secretary McNamara.*** Republican administrations have tended to downgrade the level of the systems analysis function to a directorate, while Democratic administrations have tended to raise it to the level of assistant secretary. This office was an assistant secretaryship under McNamara, was downgraded to a director under Nixon, upgraded to an assistant secretary under Carter, downgraded to a director under Reagan, then upgraded late in the Reagan Administration. This office tended to challenge programs submitted by the military services, so upgrading its status implied less authority for the military services and downgrading it implied more.

While these cycles in acquisition are important, the overwhelming trend over the 40-year period has been toward **standardization and institutionalization of the acquisition process.** During the immediate post-war period, there was little standardization of the acquisition process. Each service managed the acquisition of its own weapon systems. Later, the concept of concurrent development and production made control of the process difficult. Program management evolved as a result of the problems of concurrency. However, there was not a lot of red tape as we know it today in programs. Because of the perceived threat, many programs were fast-tracked. During the 1960s, the acquisition process became more institutionalized. By the end of the 1950s, in order to start a program, advocates had to justify it through a Development Concept Paper (DCP) in a standard format. The PPBS and systems analysis also involved more hurdles for a program to get through. In addition, the institution of SARs provided a way for programs to be compared with one another in terms of cost, schedule, and performance. The Nixon administration brought increased codification of acquisition regulations. The Packard initiatives included more emphasis on prototyping and more autonomy for the services in the execution process. During the Carter administration, the key development was more detailed resource allocation from the Defense Resources Board. During Reagan, a key initiative was the fraud, waste, and abuse campaign. Mandated competition was another DoD initiative--Congress eventually required it.

E. ACQUISITION INITIATIVES IN THIS STUDY

Major acquisition initiatives are listed in the taxonomy in Table II-1. Several of these initiatives have gone in and out of style at different times. For example, there have been elements of competition in the 1950s, 1960s, and 1970s as well as the 1980s. There were many prototypes in the 1940s and the 1950s, very few in the 1960s, and then more again in the 1970s. Selected programs are being prototyped or planned to be prototyped in the 1980s. The initiatives chosen for further analysis represent acquisition options relevant today.

Table II-1. Acquisition Initiatives Taxonomy

Life Cycle Strategies/Policies	**Management Techniques**
Development	Independent cost estimates
Pre-planned product improvement	Life-cycle costing
Teaming (competition)	Technical risk assessment
Prototyping	Cost-performance tradeoff
Concurrency	Mission element need statement
Fly-before-buy	Milestone reviews/DoD Directives and Instructions
Design-to-cost	Reorganization/commissions
Multi-service (efficiency)	Centralization/decentralization cycles
Multi-national (technical enhancement)	Baselining
	Independent testing
Procurement	
Leader-follower/dual source (competition)	**Regulatory and Administrative Policies**
Breakout	Profit controls
Multi-year	Regulations/reporting requirements
Head-to-head (competition)	Standards and specifications
Foreign military sales	Set asides/small and minority business
Contractual	Streamlining
Incentives/awards	
Cost plus fee	
Fixed price (development and procurement)	
Total package procurement	
Warranties	

Six initiatives were selected for analysis:

- *Prototyping* has been practiced in several aircraft programs, (including the A-10, F-16, F/A-18, AH-64A, and UH-60A programs), in missile programs such as Harpoon, HARM, and Hellfire, and in avionics programs like LANTIRN, OTH-B radar, and SINCGARS. Prototyping is designed to improve the development process by building one or more detailed test articles early on. The analytic issue is whether the upfront cost of doing this is recouped in more efficient FSD and production processes.

- *Competition* has been practiced for years in subsystems and is becoming increasingly popular in major systems, particularly in missile programs. By competition we mean dual sourcing in production, not the competition of companies for FSD or production contracts, which is fairly routine. Dual sourcing of major systems often requires a considerable investment in technology transfer and qualification. The analytic issue is whether this cost is recouped in a less expensive total system and whether savings can be sustained over the long term as companies become accustomed to dual sourcing.

- *Multi-year procurement* involves committing the government to a procurement and funding plan for several years. Our major multi-year systems are Patriot, MLRS, Shillalegh, Stinger-RMP, UH-60A, CH-47D, TOW, NAVSTAR GPS, DSP, DMSP, and DSCS III. The analytic issue is whether the government's commitment and reduced flexibility result in a cheaper system.

- *Design-to-cost* was widely practiced in the 1970s. The initiative is to set a cost goal very early on, similarly to the way a performance goal is set, and then design to that goal. Progress toward meeting the cost goal is reported periodically. In this report, we discuss how design-to-cost worked in practice and whether there is any evidence to suggest that it reduced cost growth. Among the design-to-cost systems we studied are the F/A-18, A-10, and AH-64 aircraft programs.

- *Fixed-price development* evolved in the Navy in the early 1980s as a way of forcing contractors to share some of the risk in development. Among the systems that started out with fixed-price development contracts are F-14D, E-6A, V-22, T45TS, AMRAAM, Stinger-RMP, and JTIDS. Although these programs are mostly in the very early stages and we do not have final outcomes, we are able to examine how fixed-price development is working in practice. As a companion piece, we consider the less recent experience of total package procurement, which forced the contractor to share the risk of both development and procurement. The systems examined are the SRAM, Maverick, and C-5A.

- *Contract incentives* are frequently used to induce the contractor to reduce costs or to engage in other behavior beneficial to the government. Incentive fee contracts typically involve a cost target, and the contractor splits savings or additional costs with the government based on actual costs. Award fee contracts are more complex; typically, a list of criteria for the program manager or a review board is used to determine the fee awarded. Although we did not do as comprehensive an analysis on this initiative as on the others, we examine the results from the macro-database and give our impressions from interviews with program offices and contractors.

F. QUANTITATIVE ASSESSMENT OF PROGRAM OUTCOMES

One of the major problems in assessing the quality of the current acquisition process is multiple goals and the lack of agreement on which goals are most important. In at least one sense, one can conclude that the acquisition process has been successful: the territory of the United States has not been attacked since World War II, and the deterrent effect of our weapon systems is certainly at least partially responsible for this.

The emphasis on quantitative assessment of program outcomes began in the McNamara era with the introduction of the SAR and has continued ever since. The acquisition process has typically been assessed in terms of:

- The achieved functional performance of the system relative to the requirements
- The meeting of planned development and production schedules
- The cost of the system relative to planned cost (References II-18 through II-24).

Cost is frequently cited as the goal that is weighted lowest by DoD decisionmakers and higher by Congress. However, Congress is also subject to pressure from constituents who work in defense-related industries. The temptations for Congress to compromise by trimming a little out of each program rather than canceling whole programs are enormous. There have been many attempts to improve the quality and independence of the cost-estimation process. Cost estimators still must contend with changes in requirements, schedules, and technical make-up, as well as economic and quantity changes. Also, it is not easy to quantify the impact of major technological advances on cost.

Development and production schedules have always been a matter of concern. There are incentives to underestimate the schedule initially in order to get a program going. Again, as with cost, technological advance and its impact on schedule are not easy to quantify.

Achieving planned functional performance is the goal typically given highest priority. Systems have generally tended to meet their performance goals (II-18). In this study, we have concentrated on evaluating cost and schedule outcomes, since these appear to be the goals that pose the most problems for the acquisition system.

REFERENCES

[II-1] Nelson, J. R., and Harold S. Balaban. *Acquisition Strategy Guide*. Defense Systems Management College, July 1984.

[II-2] Nelson, J. R., and Karen W. Tyson. *A Perspective on the Defense Weapons Acquisition Process*. Institute for Defense Analyses, Paper P-2048, September 1987.

[II-3] Logistics Management Institute. *Defense Acquisition Background Papers*. Vols. 1 and 2. June 1986.

[II-4] The Commission on Organization of the Executive Branch of the Government. "The National Security Organization: A Report to the Congress." February 1949. (Main Report and Appendix G-Task Force Report).

[II-5] Rockefeller, Nelson A. *Report of the Rockefeller Committee on Department of Defense Organization*, April 11, 1953.

[II-6] U.S. Commission on Organization of the Executive Branch of the Government *Business Organization of the Department of Defense, A Report to the Congress.*, 1955.

[II-7] Blue Ribbon Defense Panel. *Report to the President and the Secretary of Defense on the Department of Defense*, 1970.

[II-8] *Report of the Commission on Government Procurement*, 1972.

[II-9] Rice, Donald. *Defense Resource Management Study*. Washington, D.C.: U.S. Government Printing Office, February 1979.

[II-10] Grace, Peter J. *President's Private Sector Survey on Cost Control*. 1984.

[II-11] *A Quest for Excellence*–Final Report to the President by the President's Blue Ribbon Commission on Defense Management: The Packard Commission (1986).

[II-12] Symington, Stuart. "Report to Senator Kennedy from the Committee on the Defense Establishment," 1960.

[II-13] Office of Federal Procurement Policy, *Proposal for a Uniform Federal Procurement System* and *Supplemental Volume I: Proposed Legislative Amendments with Section-By-Section Analysis*, 1982.

[II-14] Defense Science Board Task Force, *Transition of Weapons Systems from Development to Production*, 1983.

[II-15] Acquisition Advisory Group, "Report to the Deputy Secretary of Defense." 1975.

[II-16] Defense Science Board, "Report of the Acquisition Cycle Task Force." 1978.

[II-17] Department of the Air Force, Air Force Systems Command. *The Affordable Acquisition Approach Study*, 1983.

[II-18] Rich, Michael, and Edmund Dews. *Improving the Military Acquisition Process*. The Rand Corporation, R-3373-AF/RC, February 1986.

[II-19] Perry, R. L., et al. *System Acquisition Experience.* The Rand Corporation, RM-6072-PR, November 1969.

[II-20] Perry, Robert, Giles K. Smith, Alvin J. Harman, and Susan Henrichsen. *System Acquisition Strategies.* The Rand Corporation, R-733-PR/ARPA, June 1971.

[II-21] Dews, E., et al. *Acquisition Policy Effectiveness: Department of Defense Experience in the 1970s.* The Rand Corporation. R-2516-DR&E, October 1980.

[II-22] Asher, Norman J., and Theodore F. Maggelet. *On Estimating the Cost Growth of Weapon Systems.* Institute for Defense Analyses, P-1494, June 1980 (Revised September 1984).

[II-23] U. S. Congressional Budget Office. *A Review of the Department of Defense December 31, 1983 Selected Acquisition Report (SAR).* Congressional Budget Office, Special Study, June 1984.

[II-24] U. S. General Accounting Office. *Weapons Cost: Analysis of Major Weapon Systems Cost and Quantity Changes.* General Accounting Office, GAO/NSIAD-89-32FS, November 1988.

III. ACQUISITION PROGRAM DATA

A. PROGRAMS IN THE SAMPLE

A sample of 89 acquisition programs was selected for analysis. The programs, listed in Table III-1, were selected to represent the following categories of equipment:

- Tactical aircraft
- Electronic aircraft
- Helicopters
- Other aircraft
- Air-launched tactical munitions
- Surface-launched tactical munitions
- Electronics/avionics
- Strategic missiles
- Satellites.

The sample includes acquisitions managed by the Army, Navy, and Air Force and both programs that are considered successful and those that encountered problems, which were resolved with varying degrees of success (including cancellation). In order to investigate differences in acquisition program outcomes between new and modified systems, the sample contained 56 new programs and 33 modification programs.

The sample is spread over approximately 32 years when grouped by FSD start. Nearly all programs in the sample are either still in production and in service, or are previous versions of weapon systems that are still in production or in service. For the development analysis, we excluded programs fewer than three years past the start of full scale development. For the production analysis, we excluded programs with fewer than three years of production experience. For this analysis, we have development information on 82 programs and production information on 73 programs.

Table III-1. Programs In the Acquisition Database

Tactical Aircraft	Electronic Aircraft	Helicopters	Other Aircraft	Air-Launched Tactical Munitions	Surface-Launched Tactical Munitions	Electronics/ Avionics	Strategic Missiles	Satellites
F-14A	E-3A	UH-60A	C-5A	AIM-7E	MLRS	ASPJ[a]	ALCM	DMSP
F-14D[a]	E-4	AH-64A	C-5B	AIM-7F	CLGP	JSTARS[a]	Tomahawk	NAVSTAR GPS
F-15	EF-111A	OH-58D	FB-111A	AIM-7M	5-Inch GP	JTIDS[a]	Trident II	DSP
F-16	S-3A	CH-47D	V-22	AIM-9L	STD MSL 2	LANTIRN[a]	GLCM	DSCS III
F/A-18	E-2C	Cheyenne[a]	C-17A	AIM-9M	Patriot	MLS[a]	Small Missile	
A-10	E-6A		B-1A[a]	AIM-54A	Pershing II	OTH-B[a]	(ICBM)[a]	
F-5E	EA-6B[a]		B-1B	AIM-54C	Lance	TRI-TAC[a]	Minuteman II	
AV-8A	LAMPS		T45TS	HARM	Roland[a]	WIS[a]	Minuteman III	
AV-8B	P-3C			Harpoon	Sgt. York	ADDS[a]	Peacekeeper	
				AGM-65A/B	IMP Hawk	SINCGARS[a]	SRAM	
				AGM-65D/G	Dragon		SRAM II	
				AMRAAM	Shillelagh			
				Hellfire	Mk-48			
				TOW	Mk-48 ADCAP			
				TOW 2	Mk-50			
				Condor	Stinger–Basic			
					Stinger–POST[a]			
					Stinger–RMP[a]			

Note: Database contains 89 programs: 82 development, 73 production.
[a]Development only.

B. DATA SOURCES

For each of the programs included in the sample, schedule dates, cost, production quantities, and narrative information were obtained from Selected Acquisition Reports, and the latest available editions of the Defense Marketing Service (DMS) "Missiles Market Intelligence Reports" [III-1], *Jane's Weapon Systems 1987-88* [III-2], the *Interavia* summary of weapons [III-3], and interviews with program management and contractor personnel. The SARs were used as the primary source of information because they are official government documents.

Development estimates (DEs), made at Milestone II or at the start of full scale development, of schedules, costs, and quantities were obtained from the earliest available SAR for each program. (Because some of the acquisition programs predate the 1967 initiation of SARs, their "original" estimates of schedules, costs, and quantities shown in this report may not have been the true original estimates; they may instead be subsequent revisions.) Current estimates (CEs) of schedules, costs, and quantities were obtained from the year-end SARs for the programs.

The December 1987 SAR (or the final SAR for completed programs) was the basis for our comparison of current estimates with development estimates. The December SAR is designated the comprehensive annual SAR; it is important because it coincides with the President's budget submission to the Congress. Thus, the services and OSD take care to ensure that the SAR data contained in the December SARs match budget items and the Five-Year Defense Plan (FYDP). Table III-2 is an example of a SAR Milestone schedule, and Table III-3 is an example of a SAR program's acquisition cost estimate. The SARs present cost estimates in escalated dollars as well as in constant dollars. This analysis uses the constant-dollar estimates so that inflation will not distort comparisons among programs whose DEs were established at different times.

The SAR is a highly aggregated source of cost information. We would have preferred data sources with more detail, and we did review sources such as the Contractor Cost Data Reporting (CCDR) system. Given the number of programs in our sample and the timeframe in which the effort was to be accomplished, we opted to use the SAR. The SAR is a definitive, standardized source of data with visibility at decisionmaking levels. It has a prescribed format common to all the services and allows for comparisons of cost, schedule, and quantity changes across programs. Development Concept Papers (DCPs) were reviewed to provide additional cost and schedule information in each program.

Table III-2. Example of SAR Schedule Milestones

9. (U) Schedule:

a. Milestones	Development Estimate/ Approved Program	Current Estimate
Prototype Seeker Firings	N/A Jan 77	Jan 77
AIM/RIM-7M FSD (DSARC II)	Apr 78/Apr 78	Apr 78
Commence Joint TECHEVAL	Feb 80/N/A	Jun 80
OSD Program Review	Apr 80/N/A	Aug 80
Commence IOT&E	Apr 80/N/A	Jun 81
Approval for Service Use	May 81/N/A	Nov 82
DSARC III	Jun 81/N/A	–
IOC (1st delivery to Fleet)	Jul 81/Jan 83	Jan 83
DNSARC III	–/Nov 82	Nov 82

Source: Reference [III-4].

Table III-3. Example of SAR Program Acquisition Costs

11. (U) Acquisition Cost (USN/USAF): (Current Estimate in Millions of Dollars)

a. (U) Cost	Development Estimate (FY 75-85)	Changes	Current Estimate (FY 75-89)
Development (RDT&E)	54.5	–1.2	53.3
Procurement	859.2	+577.4	1436.6
G, C&A	(681.7)	(+489.3)	(1,171.0)
Propulsion	(46.7)	(+14.0)	(60.7)
Other Hardware	(35.8)	(–13.4)	(22.4)
Procurement	(66.4)	(+19.1)	(85.5)
Total Flyaway	(830.6)	(+509.0)	(1,339.6)
Fleet Support	(19.9)	(+47.5)	(67.4)
Initial Spares	(8.7)	(+20.9)	(29.6)
Construction	–	–	–
Total FY 78 Base Year $	913.7	+576.2	1,489.9
Escalation	344.4	+924.3	1,268.7
Development (RDT&E)	(2.8)	(+5.1)	(7.9)
Procurement	(341.6)	(+919.2)	(1,260.8)
Construction	–	–	–
Total Then-Year $	1,258.1	+1,500.5	2,758.6
b. Quantities --			
Development (RDT&E)	44	–	44
Procurement	11,095	+4,179	15,274
Total	11,139	+4,179	15,318
c. Unit Cost --			
Procurement:			
FY 78 Base-Year	$.077	+.017	.094
Then-Year	.108	+.069	.177
Program:			
FY 78 Base-Year $	.082	+.015	.097
Then-Year	.113	+.067	.180

Source: Reference [III-4].

Representatives of selected contractors and program offices provided additional cost and schedule data and answered questions that surfaced during review of the SARs. These interviews greatly enhanced our understanding of individual programs.

Narrative information was obtained on the applicability of various defense acquisition policies and initiatives to each of the programs included in the sample. Information was also obtained where available concerning the nature and extent of any major problems that were encountered, how the problems were managed, and what appeared to be the causes.

C. OUTCOME MEASURES

From the information we gathered, a database was developed to allow examination of program outcomes and to permit analysis of the effectiveness of acquisition initiatives in acquiring major systems. We based our measures of outcome on the following factors:

- Cost growth--development, production, and total program.
- Schedule slippage--development and production. One indicator of good program performance is the extent to which the system can be developed and produced according to plan.
- Quantity changes--development and production. Trends in quantity change give clues to such issues as reasonableness of the development plan, the degree of production stability, and the prevalence of program stretchout.

Outcome measures produced were:

- Development cost growth (DCG)
- Production cost growth (PCG)
- Total program cost growth (TPCG)
- Development schedule growth (DSG)
- Production schedule growth (PSG)
- Development quantity growth (DQG)
- Production quantity growth (PQG).

We use the word "growth" to refer to changes in cost, quantity, and schedule because in most cases the change reflects an increase in dollars, numbers, or time. However, in a few cases (such as when development or production quantities are reduced), "growth" is negative.

For each of the measures of program outcomes, we compared the program development estimate to the final (or current estimate) program outcome. Table III-4 shows cost, schedule, and quantity information, extracted principally from the SAR, for the Hellfire missile program. The development estimate information is from the initial Hellfire SAR of June 1976. The current estimate for the Hellfire program is from the most recent SAR available at the time of this study, the December 1987 SAR. The derivation of "current estimate for development estimate quantity" is described in the next sub-section.

Table III-4. Hellfire Program Schedule and Cost Summary

		Development Estimate (6/76)	Current Estimate (12/87)	Current Estimate for Development Estimate Quantity
Milestone II		2/76	2/76	2/76
Development Start Date		12/72	12/72	12/72
Development End Date (IOC)		5/83	7/86 (+48%)	7/86 (+48%)
Development Quantity		241	229	229 (-5%)
Development Cost (M $)		210.3	230.2	230.2 (+9%)
Milestone III		11/81	3/82	3/82
Production Start Date		11/81	3/82	3/82
Production End Date		9/86	9/93	9/93
Production Quantity		24,600	48,696 (+98%)	24,600
Unit One Cost (K $)		215.3	1,310.5	1,310.5
Slope of Cost-Quantity Curve		82.1%	75.0%	75.0%
Production Cost (M $)		297.9	786.9	478.6
PAUC (K $)		11.30	16.16 (+43%)	19.45 (+72%)
Total Program Cost (M $)		508.2	1,017.1	708.8
Total PAUC (K $)		20.46	20.79 (+1%)	28.55 (+40%)
Years of Actual Data				
Development	Completed			
Production	6			

Notes: All costs are in 1975 dollars. Numbers in parentheses represent percentage change.

The Hellfire program outcome summary is provided in Table III-5. The database for all the programs used in this study is found in Appendix A.

Table III-5. Hellfire Summary Parameters

Development Schedule Growth	1.44
Production Schedule Growth	2.38
Development Quantity Growth	.93
Production Quantity Growth[a]	1.98
Development Cost Growth	1.09
Production Cost Growth[b]	1.61
Total Program Cost Growth[b]	1.39

[a]Based upon the increase from the development estimate quantity to the current estimate quantity.

[b]Based upon the current estimate of the cost of the program quantity contained in the development estimate.

1. Evaluation of Cost Growth

In order to understand outcomes by program phase, we separate cost growth into development and production cost. Since production cost is much higher than development cost, it tends to drive our estimate of total program cost growth. However, development cost growth is also of interest, since it is here that the technical challenges are met.

The techniques applied in our analysis for weapon system cost growth are similar to those used in past IDA and Rand investigations of program cost outcomes (for example, see [III-1, III-2]). The following process was used to produce development cost growth ratios:

- All program cost estimates were collected in the base-year dollars specified for the program. For the Hellfire program example, this is fiscal year 1975 dollars.
- Development costs were determined for the period from program startup through initial operational capability (IOC) date. Development costs incurred after IOC were excluded because these costs were for major modifications and other changes beyond the scope of the original development effort. (For example, the Harpoon program development cost estimate has doubled since IOC due to the addition of the development effort for the submarine-launched anti-missile (SLAM) version of the missile, among other changes.)
- The development cost growth (DCG) ratios were calculated by dividing the current estimate of development cost at IOC date by the development cost estimate at SAR DE approval. For the Hellfire program, this is: $230.2 million divided by $210.3 million, for a development cost growth factor of 1.09.

Before constructing production cost growth ratios, we had to address some additional issues. First, the best information available from the SAR is the annual funding summary that appears in recent SARs. These data represent the price to the government, not strictly the total cost of the program. In this effort, "cost growth" ratios refer to price growth.

Second, many programs change their planned quantity as the program progresses through production. Therefore, some adjustment to costs is necessary to take quantity change into account. In this study, scope changes in most programs examined prevented direct comparison of SAR current estimates with the SAR development estimates. The SARs provide estimates of cost change due to quantity change (and schedule, engineering, inflation, and estimating changes). We did not use these estimates, because we found that program offices interpreted the guidelines for developing these estimates in widely divergent ways. Instead, we developed price-improvement curves from the SAR annual data for completed production years. From these curves, we calculated the cost of the originally planned quantity, the development estimate quantity (DEQ).

In the Hellfire example, procurement quantities changed from 24,600 to 48,696, a 98-percent increase. Production costs increased from $297.9 million to $786.9 million. Much of this growth in production cost had to be due to the doubling of quantities procured and not to cost growth. Using our price-improvement methodology, we estimated actual Hellfire production cost of the originally planned 24,600 missiles as $438.6 million, and calculated a production cost growth ratio of 1.61.

Several programs examined do not have annual funding detail in the SARs that allow calculation of the current production estimate at the development estimate quantity. When no detailed data were available, the slope of the learning curve was assumed to be 90 percent. The current estimates of production cost and quantity from the SAR were used to estimate first-unit cost and production cost at the development estimate quantity.

IDA estimates of total production costs were then determined by adding the SAR current estimate of development costs at IOC date to the current estimate of production cost at the development estimate quantity. In the Hellfire program, total program cost at the DEQ is estimated to be $708.8 million. The total program cost growth ratio is then 1.39.

2. Evaluation of Program Schedules

We also report estimates of schedule slippage in development and production. Development schedule growth is another indicator of how well the program did in terms of providing the system in a timely fashion. Production schedule slippage is more complicated, because it is intertwined with quantity changes. Production schedule growth, with quantity constant, often means that the program is being stretched because of cost growth or because of funding shortages. Production schedule growth, with increased quantity, often means that the program is more successful than anticipated.

Schedule growth during development of a new weapon system is normally measured by the amount of slippage experienced in a program between a fixed base date (e.g., Milestone II date or FSD contract start, whichever is earliest) to its completion. After the necessary data were collected, the development schedule growth (DSG) ratio was computed using the following formula:

$$\text{Development Schedule Growth Ratio} = \frac{\text{Actual Time (Months) from FSD to IOC}}{\text{Estimated Time (Months) from FSD to IOC}}$$

The development schedule growth for Hellfire is 1.44.

Production schedule is determined using the same technique. Production span is defined as the period from Milestone III or first production contract to production end date or the last fiscal year of planned funding. Production schedule growth (PSG) ratios are computed using the following formula:

$$\text{Production Schedule Growth Ratio} = \frac{\text{Actual Time (Months) from Production Start to Production End}}{\text{Estimated Time (Months) from Production Start to Production End}}$$

Hellfire has exhibited a 2.38 production schedule growth.

3. Evaluation of Quantity Changes

Both development quantity and production quantity changes were documented using the same technique as described above. Hellfire experienced 0.95 development quantity growth (DQG). Production quantity growth (PQG) was 1.98.

REFERENCES

[III-1] Defense Marketing Service, "Missile Market Intelligence Reports," 1988.

[III-2] *Jane's Weapon Systems 1987-1988*, 1988.

[III-3] "Aircraft Armament." *Interavia*, Vol. 2, 1982.

[III-4] OSD Comptroller, *AIM-7M Selected Acquisition Report*, December 1987.

IV. TRENDS IN ACQUISITION PROGRAM OUTCOMES

A. INTRODUCTION

Weapons acquisition programs had varying degrees of success in accomplishing cost, schedule, and quantity objectives. Table IV-1 shows selected results from our database. Although many acquisition programs have been successful, others have encountered serious problems, in spite of numerous policy changes and initiatives intended to improve the acquisition process.

Table IV-1. Statistics on Key Variables

	N	Mean	Minimum	Maximum	Standard Deviation
Total Program Cost Growth[a]	63	1.51	0.76	5.19	0.76
Development Cost Growth[a]	80	1.27	0.44	4.89	0.73
Production Cost Growth[a]	63	1.65	0.69	6.61	1.03
Development Schedule Growth	81	1.34	0.76	3.90	0.50
Production Schedule Growth	57	1.65	0.63	3.71	0.78
Development Quantity Growth	76	1.12	0.50	4.10	0.61
Production Quantity Growth	63	1.22	0.02	4.76	0.88
Development Schedule Length (months)	77	79.1	19.0	147.0	31.62
Production Schedule Length (months)	56	127.1	32.0	311.0	64.29

[a]Cost growth ratios are weighted by 1989 dollar values for total program, development, and production, respectively.

This section discusses our analysis of trends in program outcomes and examines differences in program outcomes by time period, by equipment type, by program phase, and by whether the program was a new or a modification program (program type).

B. OUTCOMES BY TIME PERIOD

As previously discussed, the purpose of analyzing outcomes by time period is to see whether broad program policy in specific time periods influenced acquisition outcomes. The time periods analyzed are the 1960s, the early 1970s, the late 1970s, and the 1980s.

Each of these periods had different acquisition policies and initiatives. In the 1960s, the idea of program management was just beginning. Initiatives used included total package procurement and concurrency. Management was centralized within OSD. In the early 1970s, the prevalent initiatives, with the influence of Deputy Secretary of Defense David Packard, included incentive contracting, prototyping, and design-to-cost. In the late 1970s, design-to-cost became institutionalized, and experiments with dual-sourcing in tactical munitions were tried. In the 1980s, initiatives included fixed-price development, multi-year procurement, and more dual sourcing.

We grouped programs into time periods according to their FSD starts because FSD is a major milestone and acquisition strategies are often determined by that point. Therefore, it seems reasonable to conclude that policies at the time of FSD have the most influence on a program. However, a typical program continues for over ten years past FSD, so it may be influenced by the policies of other periods as well.

We compare observed results in terms of cost and schedule with estimates at the time of full scale development. Table IV-2 shows cost, schedule, and quantity outcomes by time period. Figure IV-1 shows development, production, and total program cost growth by FSD start year.

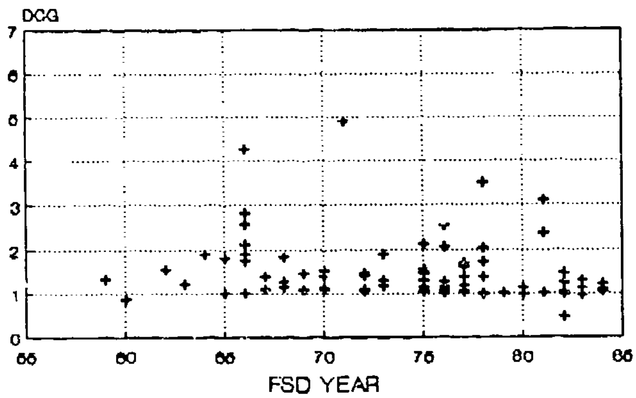
Table IV-2. Summary of Cost and Schedule Outcomes by Time Period

Time Period	N	DCG	DSG	DQG	N	PCG	PSG	PQG	TPCG
1960s	22	1.36	1.46	1.17 (20)	21	1.89	1.64 (18)	1.00	1.66
Early 1970s	12	1.25	1.24	1.33	11	1.42	1.84 (9)	1.15	1.37
Late 1970s	30	1.28	1.37	1.01	26	1.73	1.69	1.50	1.59
1970s (total)	42	1.26	1.33	1.10	37	1.63	1.73 (35)	1.40	1.51
1980s	17	1.16 (16)	1.21	1.09 (14)	5	0.91	1.07 (4)	0.85	0.92

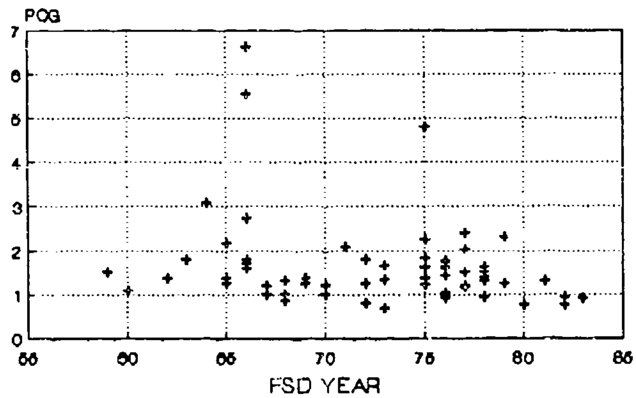
Note: Cost growth figures are dollar-weighted. Figures in parentheses are numbers of programs for cells with missing data.

The 1960s, when SAR cost estimation was in its infancy, was a period of high cost growth. Major programs such as the C-5A aircraft and the Minuteman missile were being developed. In addition, methods of tracking and managing programs were less highly structured than today [IV-1]. The cost growth in the 1960s was higher than in the early 1970s. Development schedule growth was also higher in the 1960s than in later periods.

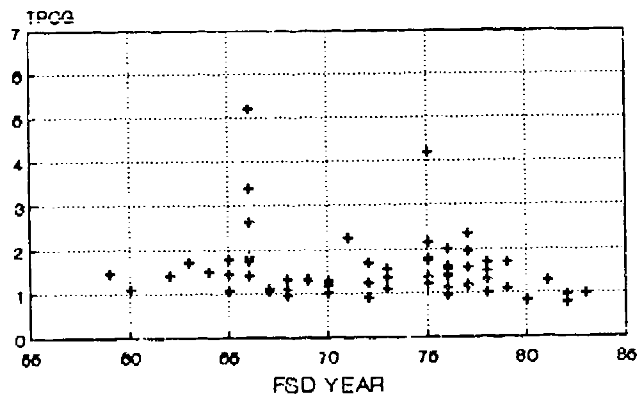
Programs with FSD start in the early 1970s, the time of the Packard initiatives, had good overall records. Cost growth both in development and in production was relatively low; however, the number of programs started in this time period was also relatively low.



Development Cost Growth by FSD Start



Production Cost Growth by FSD Start



Total Program Cost Growth by FSD Start

Figure IV-1. Cost Growth by FSD Start Year

Programs with FSD starts in the late 1970s did not do well. Their overall cost growth was almost as high as in the 1960s (1.60 versus 1.66.) Development schedule growth was a problem (1.37), although not as bad as in the 1960s (1.46). The late 1970s were a time of high inflation and declining budgets, which may have influenced cost growth. When the 1970s are considered as one period, the differences between periods are less pronounced, as shown in Table IV-2.

The jury is still out on programs begun in the 1980s. In terms of development, the 1980s programs show lower development cost growth than past programs. However, this difference is not statistically significant. The early 1980s were a time of expanding acquisition budgets and low inflation, which may also have contributed to favorable development outcomes. Only five programs (the AV-8B aircraft, the OH-58D helicopter, the C-5B transport, the B-1B bomber, and the E-6A aircraft) had sufficient production data to be included in the analysis. All of them are modifications of prior programs and thus could be expected to have lower cost growth. In addition, the five programs are in the early stages of production and have not had much time to accumulate cost growth.

The stage of program completion also affects cost growth. Figure IV-2 shows total program cost growth by the number of years to program completion. It takes time for programs to revise cost estimates as problems arise.

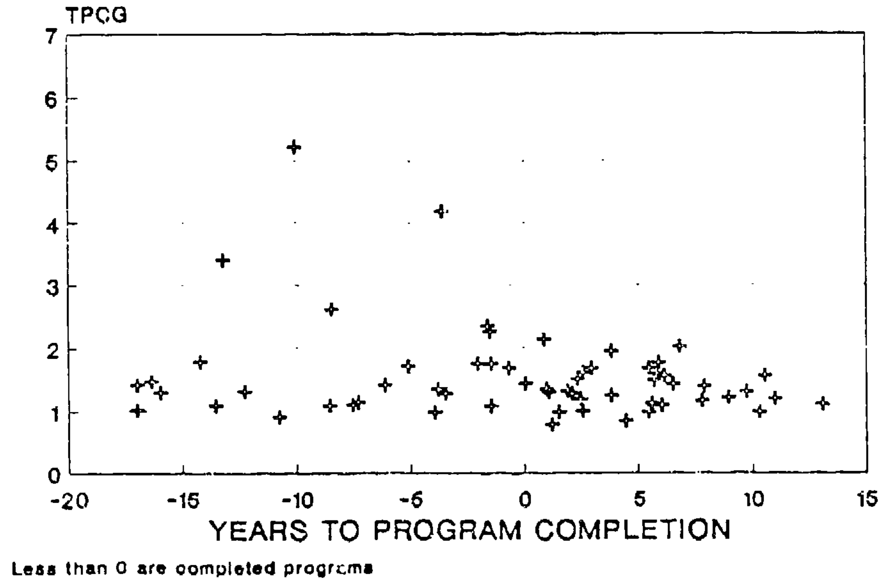


Figure IV-2. Total Program Cost Growth by Years to Completion

Other analysis provides support for this idea. Table IV-3 shows mean cost growth for complete and incomplete programs. Cost growth is substantially higher in the completed programs. Mean total program cost growth is 1.92 for completed programs and 1.30 for incomplete programs.

Table IV-3. Complete Versus Incomplete Programs

	No. of Programs	Complete Programs	No. of Programs	Incomplete Programs
TPCG	23	1.92	33	1.30
PCG	23	2.24	33	1.34
PQG	23	0.86	33	1.47
PSG	22	1.49	32	1.82
DCG	23	1.42	41	1.18
DSG	23	1.59	42	1.24
STRETCH	22	3.71[a]	32	1.67

Note: Cost growth figures are dollar-weighted.
[a]Condor (STRETCH = 56) excluded.

Regression analysis (see Table IV-4) also shows that incomplete programs tend to report less cost growth. We examined total program cost growth as a function of an index variable set to 1 for incomplete programs. Results were statistically significant at the level of .05.

Table IV-4. Regression on Total Program Cost Growth as a Function of Incompletion

Intercept	Incomplete	R^2
1.868	–0.495[a] (–2.41)	.10

[a]Statistically significant at .05 level. T-statistic is in parentheses.

Dews et al. [IV-2] also found that cost growth tended to accumulate in production for a sample of 1970s programs. Cost growth accumulates gradually as experience is gained, and cost estimates have to be revised to reflect experience. If the end of the production run is more than five years into the future, then cost estimates for the out-years would not appear in the FYDP and might not be revised immediately.

Other caveats about the 1980s programs include:

- The relative need to "sell" a program at a given time may influence the initial development estimate of both cost and schedule. When budgets are fairly generous and expected to increase, obtaining funds is relatively easy, so there is no incentive to underestimate. However, if budgets are tight, there may be an incentive to underestimate costs in order to get the program funded.

- Although the 1980s programs appear to be doing well, they are not very far along. We have only six 1980s programs, and we have on average only four to five years of production data for them. If cost growth tends to appear late in the program, then these programs should be reevaluated when they have more experience.

C. OUTCOMES BY EQUIPMENT TYPE

The purpose of analyzing outcomes by equipment type is to see whether outcomes are substantially different for the various classes of systems examined. Figure IV-3 shows cost and schedule outcomes by equipment type and Table IV-5 shows these outcomes in more detail. We also show additional detail for all aircraft (Table IV-6) and all tactical munitions (Table IV-7).

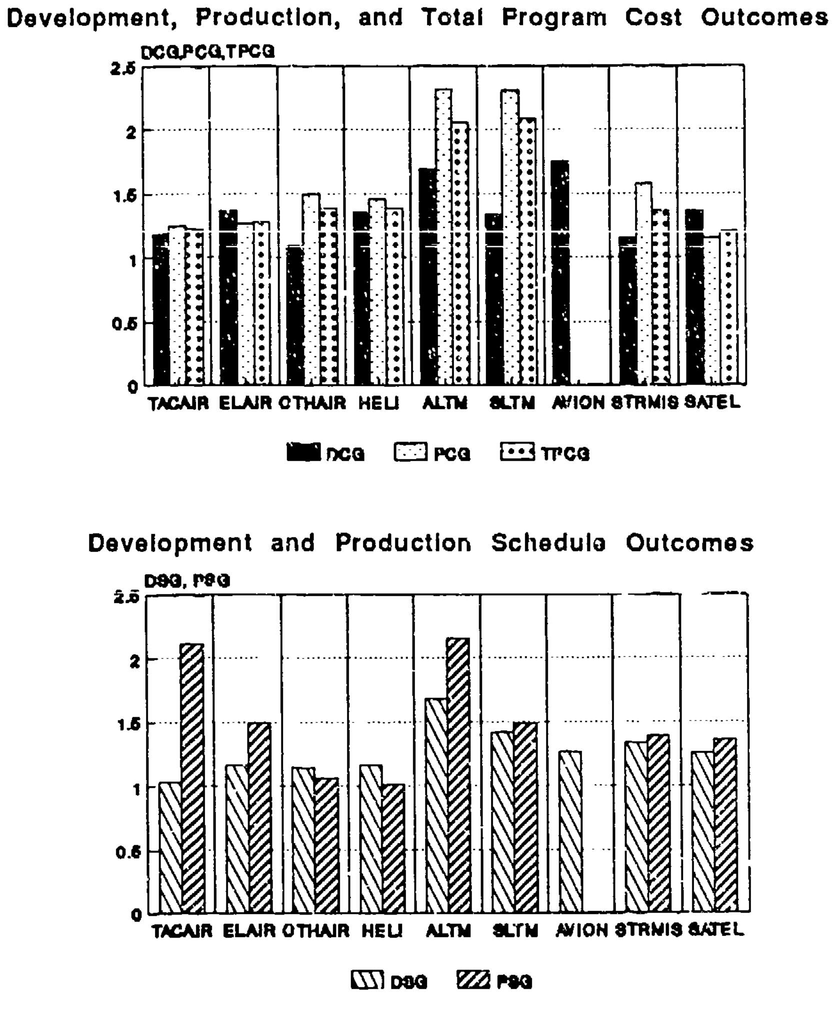


Figure IV-3. Cost and Schedule Outcomes by Equipment Type

Table IV-5. Summary of Cost and Schedule Outcomes by Equipment Type

Equipment Type	N	DCG	DSG	DQG	N	PCG	PSG	PQG	TPCG
Tactical Aircraft	8	1.18	1.03	1.10 (7)	8	1.25	2.12 (7)	1.65	1.23
Electronic Aircraft	9	1.37	1.16	1.21 (8)	9	1.27	1.49 (6)	1.07	1.28
Other Aircraft	5	1.09	1.14 (6)	0.83 (4)	4	1.50	1.06 (3)	0.74	1.39
Helicopters	5	1.36	1.16	0.93	4	1.46	1.01	0.95	1.39
Air-Launched Tactical Munitions	16	1.69	1.68	1.43	15	2.32	2.16 (14)	1.42	2.05
Surface-Launched Tactical Munitions	18	1.34	1.42	0.95	12	2.31	1.49	0.87	2.08
Electronics/Avionics	7	1.75	1.27	1.39	0	–	–	–	–
Strategic Missiles	8	1.15	1.34	0.87 (7)	7	1.58	1.39	1.47	1.37
Satellites	4	1.37	1.26	1.00	4	1.15	1.36	1.35	1.20

Note: Cost growth figures are dollar-weighted. Figures in parentheses are numbers of programs for cells with missing data.

Table IV-6. Aircraft Outcomes by Time Period and Program Type

		1960s	Early 1970s	Late 1970s	1980s
New	DCG	1.27 (4)	1.17 (6)	1.15 (4)	1.12 (1)
	DSS	1.09 (4)	1.18 (6)	1.14 (4)	1.27 (1)
	DQG	1.17 (4)	1.19 (6)	1.00 (4)	1.00 (1)
	PCG	1.64 (3)	1.22 (6)	1.40 (4)	0.92 (1)
	PSS	1.79 (3)	1.52 (6)	1.99 (4)	–
	PQG	0.96 (3)	0.99 (6)	1.98 (4)	1.07 (1)
	TPCG	1.48 (3)	1.21 (6)	1.34 (4)	0.96 (1)
Modified	DCG	1.83 (3)	1.35 (2)	1.82 (2)	0.98 (5)
	DSS	1.14 (3)	0.91 (2)	1.38 (2)	1.01 (6)
	DQG	1.00 (2)	1.00 (2)	1.00 (2)	0.83 (3)
	PCG	1.62 (2)	1.13 (2)	1.44 (2)	0.91 (4)
	PSS	0.80 (1)	–	1.43 (2)	1.07 (4)
	PQG	0.78 (1)	2.05 (2)	1.11 (2)	0.79 (4)
	TPCG	1.63 (1)	1.18 (2)	1.49 (2)	0.92 (4)

Note: Cost growth figures are dollar-weighted. Figures in parentheses are numbers of programs for cells with missing data.

Table IV-7. Tactical Munitions Outcomes by Time Period and Program Type

		1960s	Early 1970s	Late 1970s	1980s
New	DCG	1.43 (8)	1.36 (2)	1.47 (7)	1.35 (2)
	DSS	1.57 (8)	1.26 (2)	1.49 (7)	1.55 (2)
	DQG	1.00 (8)	0.84 (2)	0.83 (7)	0.83 (2)
	PCG	2.98 (8)	1.75 (2)	1.90 (6)	–
	PSS	1.52 (7)	2.03 (2)	1.56 (6)	–
	PQG	0.83 (7)	0.70 (2)	1.13 (6)	–
	TPCG	2.46 (7)	1.64 (2)	1.83 (6)	–
Modified	DCG	2.66 (3)	1.96 (2)	1.30 (8)	1.01 (2)
	DSS	2.05 (3)	1.73 (2)	1.48 (8)	1.27 (2)
	DQG	1.98 (3)	2.55 (2)	1.14 (8)	1.25 (2)
	PCG	1.72 (3)	2.07 (1)	2.84 (7)	–
	PSS	2.73 (3)	2.76 (1)	1.87 (7)	–
	PQG	1.16 (3)	1.23 (1)	1.73 (7)	–
	TPCG	1.72 (3)	2.25 (1)	2.47 (7)	–

Note: Cost growth figures are dollar-weighted. Figures in parentheses are numbers of programs for cells with missing data.

Tactical munitions programs have experienced the highest total program cost growth of any class of system examined. Air-launched tactical munitions experienced the second highest development cost growth (1.69) and the highest production cost growth (2.32). Surface-launched tactical munitions fared somewhat better than air-launched munitions in development (1.34), but also experienced considerable production cost growth (2.31).

Tactical munitions probably have a higher percentage of technological content than other weapons systems. The guidance and control system usually pushes the state of the art and represents two-thirds to five-sixths of the cost of the total system. But tactical munitions systems are not very glamorous and therefore may not receive as much high-level management attention as needed.

Experience with other equipment types generally were much better. Aircraft, satellites, and strategic missiles tend to have lower total program cost growth than tactical munitions.

Electronics programs, which exhibited the highest cost growth in development, were examined only for development cost growth because we could not disaggregate production costs from the SARs. However, the rationale that applies to the history of cost growth for munitions programs very likely applies to electronics programs as well.

D. OUTCOMES BY PROGRAM PHASE

We examined cost growth in development and in production separately (as shown in Tables IV-1 and IV-2 and IV-5 through IV-7). From Table IV-1, we can see that cost growth is less on average in development (1.27) than in production (1.65). This may be because there is less time between the estimate and the actuals in development--by the time production is completed, by contrast, the DE may be 15 years old or more. The estimate of total program cost growth is heavily influenced by production cost growth. Our quantity-adjusted production cost is on average 3.5 times the size of development cost in real terms.

Schedule growth in development goes hand-in-hand with cost growth in production--there is a .540 correlation between the two (statistically significant at .0001). Development schedule growth is also associated with total program cost growth (.611 correlation, statistically significant at .0001).

In electronic aircraft and in satellites (Table IV-5), cost growth is higher in development than in production. One might hypothesize that this is because of the higher content of technology in these items. However, tactical munitions have similar technical content, but cost growth is higher in production than in development.

The highest development cost growth is in electronics/avionics (1.75), for which we have no corresponding measure of production cost growth. The second highest is in air-launched tactical munitions (1.69), which makes sense considering the technical risks involved and the difficulty in selling these less-glamorous programs.

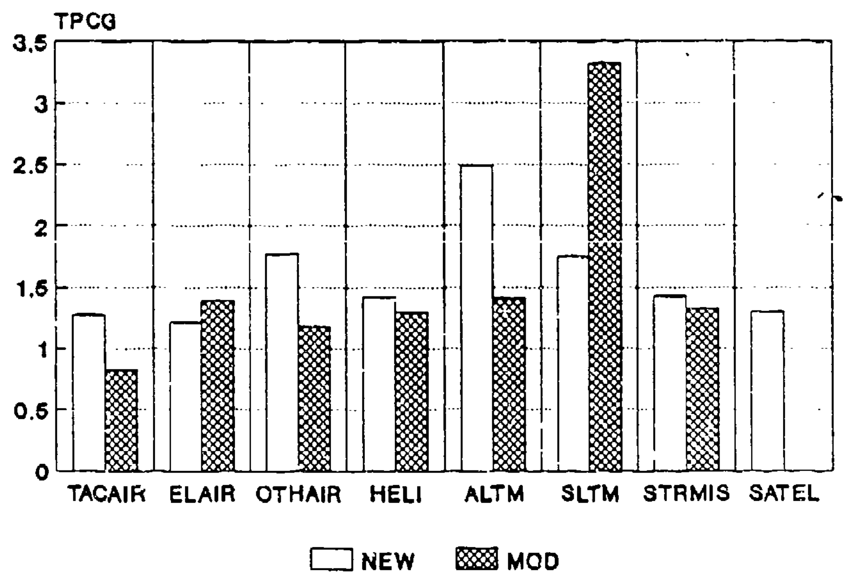
E. OUTCOMES BY PROGRAM TYPE

Finally, we analyzed program outcomes for both new development programs and modification programs. The purpose of this analysis is to see whether outcomes are substantially different between new and modification programs. Table IV-8 shows cost and schedule outcomes for new and modification programs. Figure IV-4 and Tables IV-9 and IV-10 show additional detail by equipment type and by time period.

Table IV-8. Summary of Cost and Schedule Outcomes by Program Type

Program Type	N	DCG	DSG	DQG	N	PCG	PSG	PQG	TPCG
New	48	1.30	1.34	1.05 (47)	37	1.69	1.63 (35)	1.13	1.54
Mod	32	1.20	1.35 (33)	1.23 (29)	26	1.57	1.68 (22)	1.36	1.46

Note: Cost growth figures are dollar-weighted. Figures in parentheses are Ns for cells with missing data.



Note: Avionics data not available

Figure IV-4. Total Program Cost Growth by Program Type and Equipment Type

Table IV-9. Program-Type Outcomes by Equipment Type

Program Type	N	DCG	DSG	DQG	N	PCG	PSG	PQG	TPCG
Tactical Aircraft									
New	5	1.20	1.07	1.14	6	1.29	2.27	1.77	1.27
Mod	3	1.09	0.96	1.00 (2)	2	0.77	1.27 (1)	1.31	0.83
Electronic Aircraft									
New	5	1.28	1.20	1.33	5	1.23	1.57 (4)	0.85	1.22
Mod	4	1.59	1.12	1.00 (3)	4	1.35	1.33 (2)	1.34	1.39
Other Aircraft									
New	2	1.06	1.18	0.90	1	2.15	1.19	0.66	1.77
Mod	3	1.17	1.12 (4)	0.75 (2)	3	1.17	1.00 (2)	0.76	1.18
Helicopters									
New	3	1.39	1.19	0.88	2	1.50	1.01	1.13	1.42
Mod	2	1.04	1.13	1.00	2	1.33	1.01	0.78	1.30
Air-Launched Tactical Munitions									
New	8	1.45	1.58	0.92	7	3.01	1.94 (6)	0.96	2.49
Mod	8	2.57	1.78	1.93	8	1.38	2.33	1.81	1.41
Surface-Launched Tactical Munitions									
New	11	1.37	1.45	0.89	9	1.85	1.38	0.89	1.75
Mod	7	1.28	1.39	1.03	3	4.0	1.81	0.78	3.32
Electronics/Avionics									
New	7	1.75	1.27	1.39	0	NA	NA	NA	NA
Strategic Missiles									
New	3	1.31	1.46	0.85 (2)	3	1.66	1.61	1.23	1.43
Mod	5	1.08	1.27	0.88	4	1.53	1.23	1.66	1.33
Satellites									
New	4	1.37	1.26	1.00	4	1.15	1.36	1.35	1.30

Note: Cost growth figures are dollar-weighted. Figures in parentheses are numbers of programs for cells with missing data.

Table IV-10. Program-Type Outcomes by Time Period

		1960s	Early 1970s	Late 1970s	1980s
New	DCG	1.45 (14)	1.21 (8)	1.17 (18)	1.62 (8)
	DSS	1.42 (14)	1.20 (8)	1.31 (18)	1.37 (8)
	DQG	1.05 (13)	1.10 (8)	0.97 (18)	1.17 (8)
	PCG	2.10 (13)	1.42 (8)	1.53 (15)	0.92 (1)
	PSS	1.54 (12)	1.72 (8)	1.68 (15)	–
	PQG	1.00 (12)	0.92 (8)	1.35 (15)	1.07 (1)
	TPCG	1.82 (12)	1.36 (8)	1.43 (15)	0.96 (1)
Modified	DCG	1.25 (8)	1.70 (4)	1.68 (12)	0.95 (8)
	DSS	1.52 (8)	1.32 (4)	1.45 (12)	1.07 (9)
	DQG	1.38 (7)	1.78 (4)	1.07 (12)	0.99 (6)
	PCG	1.59 (7)	1.46 (3)	2.39 (11)	0.91 (4)
	PSS	1.86 (6)	2.76 (1)	1.70 (11)	1.07 (4)
	PQG	1.00 (6)	1.78 (3)	1.71 (11)	0.79 (4)
	TPCG	1.44 (6)	1.52 (3)	2.13 (11)	0.92 (4)

Note: Cost growth figures are dollar-weighted. Figures in parentheses are numbers for cells with missing data.

As would be expected, modification programs have exhibited better cost growth experience than new programs. However, air-launched tactical munitions modification programs have experienced the highest development cost growth of any class of system examined. Costs for tactical munitions modifications are usually underestimated, because a modification often comprises a new guidance and control system, the largest part of the equipment cost.

Electronic aircraft modification programs exhibited higher cost growth in both development and production phases then new electronic aircraft. Again, this can be attributed to underestimation of the technical difficulty and the cost of integrating the electronics equipment with the airframe.

F. CONCLUSIONS

There is little indication that acquisition program outcomes are getting either substantially better or substantially worse. Development schedule growth and cost growth in development, production, and the total program remain persistent problems, even though considerable improvements have been made in the information available to program managers. The early 1970s, the time of the Packard initiatives, seems to have better program outcomes than other periods.

Our conclusions about programs begun in the 1980s are preliminary. The development schedule growth of the 1980s programs is relatively low, and this usually bodes well for the future. However, we are reluctant to draw any conclusions about the production phase because of the small number of programs in our sample and because those programs are all in the early stages of production.

Program outcomes differ depending on equipment type. Tactical munitions programs experienced the highest total program cost growth. This was foreshadowed by their cost and schedule problems in development.

Electronics/avionics programs had the highest development cost growth of any equipment type. We were unable to track the production experience of electronics/avionics systems due to data limitations--production data is usually included in the platform SARs and cannot be disaggregated. However, we have seen that problems in development tend to be followed by production problems. This, coupled with the fact that many future programs emphasize avionics heavily, suggests that these programs should be targeted for increased management attention.

As expected, modification programs exhibited lower total program cost than new programs. It is easier to stay on plan for a modification program. However, there are two equipment types for which this was not the case--air-launched tactical munitions and electronic aircraft. Both of these emphasize guidance systems or avionics and further reinforce our conclusions that these are particular problem areas.

REFERENCES

[IV-1] Gates, William R. *Department of Defense Procurement Policy: An Evolutionary Perspective.* Jet Propulsion Laboratory, Pasadena, CA, JPL 900-990, April 1987.

[IV-2] Dews, Edmund, et al. *Acquisition Policy Effectiveness: Department of Defense Experience in the 1970s.* The Rand Corporation, R-2516-DR&E, October 1979.

V. FACTORS THAT AFFECT COST GROWTH

A. INTRODUCTION

Now that the overall program outcomes have been described, we turn to a closer look at cost growth, a major concern of both DoD and Congress. We examine here some of the reasons for higher or lower cost growth. Why do some programs exhibit relatively high cost growth, while others keep closer to their plans?

Program stretch has become more common over time. It is frequently suggested that stretch has been a major contributor to cost growth. We examine these claims. (Our analysis used constant dollars--i.e., adjusted for inflation. However, unanticipated inflation may cause problems in program planning and funding. A discussion of this problem is contained in Appendix B.)

Acquisition initiatives, as described in Section II, are designed to reduce cost growth. In this section, we look at the impact of these initiatives on cost growth using the database of SAR programs.

Finally, other potential contributors to differences in cost growth are examined. While our examination is limited by the data, we believe that this is an important opportunity to examine the drivers of cost growth in a large sample of programs.

B. PROGRAM STRETCH

We examined the hypothesis that program stretch contributes to cost growth, particularly to production cost growth. The Defense Department and the Congress have sometimes met budgetary constraints by stretching out the production schedule, buying the same quantity over a longer schedule, or buying a lesser quantity over the same time period.

We measured program stretch by the ratio of production schedule growth to production quantity. A normal value of stretch is 1.0. This indicates that schedule and quantity either did not grow, or grew in proportion with one another. A stretch value of two indicates that the program relatively doubled in schedule while buying the same quantity.

Our results indicate that program stretch is a significant determinant of both production and total program cost growth. Table V-1 shows regression results for two different data sets--the full data set and a data set with outliers (defined as values more than two standard deviations from the mean) removed. (Outliers can have a large influence on regression estimates. In some cases, the removal of outliers can change an equation drastically. The outliers in this equation were SRAM, Roland, and Condor.)

Table V-1. Regression Results for Program Stretch

	Intercept	Stretch	R^2	N
Production Cost Growth				
With Full Data Set				
Unweighted	1.41	0.094[a]	42	57
		(6.26)		
Weighted	1.36	0.097[a]	.57	57
		(8.55)		
With Outliers Removed				
Unweighted	1.30	0.085[b]	.07	54
		(2.03)		
Weighted	1.28	0.094[b]	.10	54
		(2.39)		
Total Program Cost Growth				
With Full Data Set				
Unweighted	1.37	0.070[a]	.44	57
		(6.56)		
Weighted	1.30	0.073[a]	.53	57
		(7.83)		
With Outliers Removed				
Unweighted	1.27	0.080[b]	.08	54
		(2.16)		
Weighted	1.19	0.098[a]	.14	54
		(2.94)		

Note: Numbers in parentheses are t-statistics.
[a]Significant at .01 level.
[b]Significant at .05 level..

In both data sets, stretch is statistically significant. Figure V-1 illustrates production cost growth by program stretch.

To interpret the coefficients, we use the unweighted PCG estimate from the full data set as an example. With STRETCH=1 (the norm), PCG is estimated by:

$$1.41 + (0.094*1) = 1.504.$$

If STRETCH=2, then PCG is estimated by:

$$1.41 + (0.094*2) = 1.598.$$

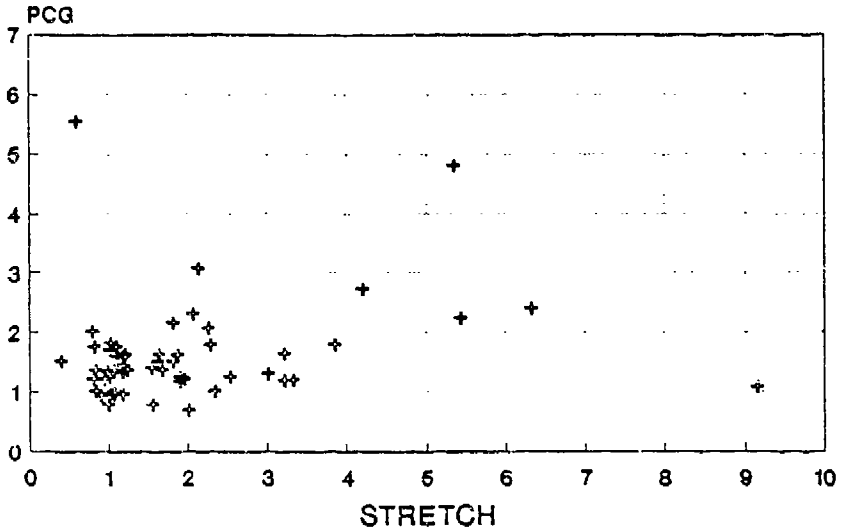


Figure V-1. Production Cost Growth by Stretch

Thus, using this equation, each one unit increase in stretch is associated with an increase of .094 in the production cost growth ratio, or 9.4 percentage points. Other estimates ranged from 7 to 10 percentage points. These are in line with estimates found in a report on stretch by the Congressional Budget Office [V-1], which surveyed assessments of the military services and weapons producers. These estimates ranged from around 8 percent to over 50 percent for each unit increase in stretch.

C. ACQUISITION INITIATIVES TO IMPROVE PROGRAM OUTCOMES

We used regression analysis to examine whether the acquisition initiatives we studied are associated with lower cost growth. We analyzed the full data set and the following subsets of equipment types:

- Aircraft--includes tactical aircraft, electronic aircraft, helicopters, and other aircraft.
- Tactical munitions--includes air-launched and surface-launched tactical munitions.
- Other--includes electronics/avionics (development only), strategic missiles, and satellites.

The initiatives included:

- Multi-year procurement

- Competition in production
- Prototyping
- Design-to-cost
- Total package procurement
- Fixed-price development
- Contract incentives in development
- Contract incentives in production.

In all cases, the dependent variable was cost growth, whether development, production, or total program cost growth. Fixed-price development was tested only in development, since none of the FPD programs was far enough along in production to be included. Table V-2 gives only those results for which the initiatives were statistically significant.

Table V-2. Regression Results for Acquisition Initiatives

Outcome Measure	Programs	Initiative	Intercept	Coefficient	R^2	N
TPCG	Aircraft	Total Package Proc.	1.22	0.54[b] (2.03)	.15	25
TPCG	Other	Total Package Proc.	1.32	2.07[a] (5.94)	.80	11
TPCG	Other	Incentives, FSD	2.21	–0.96[a] (–2.52)	.41	11
TPCG	Other	Incentives, Prod	1.94	–0.79[b] (–2.19)	.35	11
PCG	All	Total Package Proc.	1.57	1.27[a] (2.13)	.07	63
PCG	Aircraft	Total Package Proc.	1.21	0.94[a] (3.15)	.30	25
PCG	Other	Total Package Proc.	1.36	4.16[a] (13.71)	.95	11
PCG	Other	Incentives, FSD	2.88	–1.57[b] (–2.08)	.32	11
DCG	Other	Fixed Price Dev.	1.51	1.60[b] (2.05)	.20	19
DCG	Other	Incentives, FSD	2.00	–0.77[a] (–2.23)	.23	19

Note: Numbers in parentheses are t-statistics.
[a]Significant at .05.
[b]Significant at .10.

In development, fixed-price development appeared to contribute to increased cost growth for the "other" category of programs. However, this variable was significant only at the .10 level, and it is based on limited data. In the same category, contract incentives in FSD were related to reduced development cost growth (significant at .05).

In production, total package procurement was related to increased cost growth for the full data set and for aircraft and other programs. In the "other" category, incentives in FSD were related to reduced production cost growth (.10 significance).

With respect to total program cost growth, total package procurement again was related to increased cost growth. In the "other" category, incentives in FSD and in production were both related to reduced total program cost growth.

These results have some limitations:

- This is an aggregate analysis, and for some initiatives, aggregate comparisons may not be the most appropriate. For example, in prototyping, it does not make sense to include follow-on modification programs in the analysis. The individual sections on the initiatives, Sections VI through XI, contain analyses specific to those initiatives.
- This analysis is based solely on the criterion of whether an initiative was applied or not. There is nothing to indicate how strongly or appropriately the initiative was applied. For example, all instances of competition, whether appropriate or not, are lumped together. All instances of design-to-cost, whether strongly applied or not, are included.

D. EXPLAINING ACQUISITION COST GROWTH

Using our database, we investigated factors that might account for or be considered drivers of total program cost growth. These included:

- Performance in development. A reasonable hypothesis would be that a smooth development process (on time and on cost) would make smooth production more likely. Programs that get into difficulty in development might be more likely to have problems overall.
- Equipment type. In this study, we analyzed a variety of equipment types. Tactical munitions appeared to have higher cost growth than other systems.
- New starts versus modifications of existing systems. It might be expected that new starts are riskier and thus more subject to cost growth pressures.

- Acquisition initiatives. Specific initiatives by the Department of Defense that have targeted program cost may have an impact.
- Schedule length. Long programs have more opportunity to accumulate cost growth.
- Program stretch. Buying the same quantity over a longer period of time may increase cost growth.

We tested several formulations of the candidate variables. Significant results are reported in Table V-3. Development schedule growth, program stretch, and development schedule length are the strongest determinants of total program cost growth that we found. All work in the direction of increasing total program cost growth.

Table V-3. Drivers of TPCG

	Intercept	DSG	Stretch	TPP	DS	R^2	F	N
Full Data Set	0.634	0.573 (4.36)	0.053 (5.20)	– –	–	0.59	37.66	56
	0.374	0.427 (3.34)	0.054 (5.85)	1.124 (3.32)	0.005 (2.36)	.68	26.41	55
Data Set with TPCG Outliers Removed	0.779	0.390 (4.02)	0.070 (2.13)	– –	– –	0.30	10.89	53
	0.560	0.300 (3.06)	0.070 (2.23)	– –	0.004 (2.60)	.38	9.86	52

Notes: All results are significant at .05 level. Numbers in parentheses are t-statistics.

E. CONCLUSIONS

The database assembled for this study created an opportunity to do quantitative analysis of the factors affecting cost growth in major weapons systems.

We examined the hypothesis that program stretch contributes to cost growth. We found that stretch adds 7 to 10 percentage points to production cost growth in real terms. Thus, the decision to fund more programs in the face of limited budgets means a loss of efficiency.

The acquisition initiatives we studied were designed to reduce costs. We examined how these initiatives were related to cost growth. Three of the acquisition initiatives had a statistically significant relationship with cost growth for some equipment types. These include:

- Contract incentives in FSD and in production, which were associated with lower cost growth.
- Total package procurement, which was related to increased production and total program cost growth.
- Fixed-price development, which was associated with higher development cost growth.

However, this aggregate analysis is not the final word. We measured here only whether an initiative was applied or not, not how effectively it was applied. The sections that follow discuss the effectiveness of the initiatives in more detail.

We examined several factors that might account for or be considered major drivers of cost growth. Among all of these factors, three stand out. The major drivers of total program cost growth appear to be development schedule growth, program stretch, and development schedule length.

REFERENCE

[V-1] U.S. Congressional Budget Office. "Effects of Weapons Procurement Stretch-Outs on Costs and Schedules." November 1987.

VI. MULTI-YEAR PROCUREMENT

Multi-year procurement describes the acquisition situation where DoD contracts for more than the current year's requirement. DoD's planned requirements, for up to a five-year period, are acquired without having total funds available at the time of contract award. Thus, an MYP contract is an alternative to a series of annual contracts in which the end items are procured one year at a time. Through economic quantity buys, MYP is expected to reduce the cost of procuring a weapon system.

A. BACKGROUND

The U.S. Army began testing the concept of MYP on small automotive motors in the early 1960s. DoD actively used it for weapon systems acquisition throughout the 1960s. During this period, weapons programs were typically funded with no-year (no two- or three-year obligation requirement) funds and it did not take any special authorization to award contracts on a multi-year basis. DoD claimed cost savings and a high degree of program stability [VI-1].

In 1972, the Navy cancelled a pair of shipbuilding contracts incurring cancellation charges of $388 million. Although the problems with these particular contracts were not necessarily related to the fact they were multi-year, Congress nonetheless was not pleased with such a large unfunded liability. To prevent a recurrence of these unexpected cancellation payments on multi-year contracts, Congress lished a maximum cancellation ceiling of $5 million in the FY 1973 Defense Authorization Act. Contractors refused to accept multi-year contracts for major systems acquisitions with only $5 million cancellation ceiling. If a major program were cancelled after the first year, the contractor would face significant unrecovered costs. For the remainder of the 1970s, the effect of the limit on cancellation ceilings was to virtually eliminate the use of MYP on major systems acquisition [VI-1].

A Defense Science Board (DSB) study rekindled interest in MYP by estimating the DoD could save 10 to 15 percent of program costs by using MYP on major programs. DoD endorsed the DSB position, and Deputy Secretary of Defense Fra k Carlucci adopted expanded use of multi-year procurement as one of the "Carlucci Initiatives."

Congress passed legislation in the FY 1982 Authorization Bill, Public Law 97-86, that gave MYP viability in major weapon systems acquisition. Public Law 97-86 authorized:

- Cancellation ceilings of $100 million without notifying Congress. Thirty days notice to Congress was required for contracts with ceilings in excess of $100 million. Ceilings could either be funded, or left unfunded and carried as a contingent liability.
- Use of MYP with annual funds for supplies and services.
- Broadened coverage of the cancellation ceiling to include recurring costs (costs of out-year components, parts, and work in process), as well as previously allowed non-recurring costs and economic lot buys.
- Advanced buys, both in the case of long-lead-time items and economic order quantities, for more than one year beyond the current year's requirements.
- MYP contracts to cover up to a five-year period.

The Department of Defense (DoD) immediately claimed savings of $325 million by using MYP for FY 1982 weapon system programs. In 1983, the Presidential Private Sector Survey by the Grace Commission advocated greater use of MYP and stated that DoD might save as much as $3 billion over the next several years with more aggressive use of MYP [VI-1, VI-2]. However, in 1983 Congress placed limits on the use of MYP. Advance congressional notification of all MYP programs with cancellation ceilings over $20 million, rather than over $100 million, was required. Congressional notification of all economic order quantity (EOQ) purchases was required. Congress also imposed a requirement that all four Defense Budget committees be notified of programs selected as MYP candidates.

B. BENEFITS AND WEAKNESSES

In its fiscal years 1982 through 1989 budget requests, OSD proposed at least 60 candidates to Congress for approval of multi-year procurement authority. OSD estimated a total potential savings for these programs of approximately $13.4 billion then-year dollars. Total procurement value of the multi-year candidates was estimated as $78.8 billion with multi-year contracting. This was estimated to average about 13 percent less than the cost of procurement of the systems on an annual contracting basis. The information was accumulated from the FY 1982 through FY 1989 OSD "Justification of Estimates for Multi-Year Procurement."

The OSD justification of cost estimates often have provided estimates of the source of the savings. The total estimated savings and breakout by source of savings for the FY 1987 candidates are shown in Table VI-1.

Table VI-1. Sources of Estimated Savings

Source	Percentage of Total Estimated Savings
Vendor Procurement	54.8
Manufacturing	36.1
Inflation	7.9
Other	1.2
Total	100.0

This breakout of source of savings has proved to be typical for all MYP candidates. The majority of savings in a multi-year arrangement are associated with procurement of vendor items on a more economical basis than is possible with a series of annual procurements. Manufacturing savings are achieved by increased prime-contractor manufacturing efficiencies made possible by stable production rates and the increased length of production. Inflation savings are attributed to earlier procurement of manufacturing materials. The "other" category generally includes savings due to reduced administrative cost of a contract under the MYP scenario.

In spite of the potential benefits, several weaknesses of MYP must be considered. They are:

- Multi-year contracting can reduce future budget flexibility for DoD and the Congress. This is especially true in times of budget uncertainty and declining budgets. If budget conditions are expected to be unpredictable (or general funding to be unstable) during the timeframe of a proposed multi-year contract, and if changes are forced on the MYP program, OSD has two options: (1) renegotiate the MYP contract or (2) cancel the contract. In either case, the result is likely to be more costly than a series of annual contracts over the same time period would be.
- Multi-year contracting requires a substantial amount of up-front funding. The government will incur higher borrowing costs associated with accelerated expenditures under multi-year contracting. Cost savings must offset these additional government borrowing costs.
- Multi-year procurement contracts often specify a contractor cancellation fee. In order for MYP to work, the contractor must feel protected enough to procure from vendors at economic rates. The cancellation fees ensure that if the contract is terminated, the contractor and vendors to the prime contractor will

not go entirely uncompensated for procurement of parts or materials greater than would have been procured in an annual contracting environment.

- MYP can result in loss of design flexibility. Unanticipated changes in the threat and incorporation of rapid changes in technology cannot be easily addressed in the multi-year environment. Renegotiation of the multi-year contract is generally required. Even so, changes may be more difficult to incorporate than under an annual contract. This is because the prime contractor may produce heavily in the early years of the multi-year contract and may have tooled accordingly. At the very least, the prime contractor will have made commitments with vendors for materials, specified in the earlier design, that would make an immediate shift to the enhanced design costly.
- Use of MYP may also reduce the funding available for other acquisition programs. The full-funding requirements used under MYP can result in the crowding out of other programs. The services' flexibility in assigning priorities among various programs, and to reallocate funding among the programs, is reduced by MYP [VI-6, VI-7].

Primarily because of the funding commitments discussed in this section, neither the services nor the Congress have been willing to commit many programs to multi-year funding. Historically, less than 50 percent of the the candidates proposed in any fiscal year are approved for multi-year funding.

C. TYPICAL APPLICATION

In Public Law 97-86, criteria were established that multi-year candidates must meet with congressional approval prior to authorization of funding. In order for MYP to be of benefit to the government, the estimated cost savings are expected to be significant because multi-year contracting can reduce future budget flexibility. Whether savings are enough to offset the risks imposed by reduced budget flexibility is judged by Congress. In the past, Congress has asked the General Accounting Office to make this assessment [VI-3 through VI-5]. To do this, program risk in the following areas is assessed:

- Confidence in the cost estimate
- Requirement stability
- Funding stability
- Configuration or design stability.

Confidence in the cost estimate requires that the contract cost estimates and the anticipated cost savings be realistic. Cost savings are figured as the difference between cost estimates, proposals, or negotiated prices for the multi-year contract and the cost of procuring the same quantities in the same timeframes with successive annual contracts. The services generally use proposals or negotiated contracts from the applicable contractor on both an annual and multi-year basis, and then compare and analyze those proposals to estimate savings from the MYP approach.

To provide greater assurance of the validity of estimated savings, the Congress has mandated a two-step multi-year approval process: Proposed multi-year contract costs are provided both with the budget submission and again just before contract award. Defense Appropriation Acts since FY 1984 have included language that reserves final multi-year approval until negotiated contract prices are submitted to the House and Senate Armed Services and Appropriations Committees at least 30 days before the contract award. This allows the committees to compare the estimates presented in the justification packages with the actual proposed contract amounts.

A stable requirement means the total quantity and procurement rate will not vary substantially (principally avoiding downward adjustments) over the term of the multi-year contract. Decreases in the procurement quantities can cause termination of the multi-year contract and create unit cost increases, which could reduce savings.

Both DoD and the Congress must be committed to ensuring that sufficient funds are provided to complete the multi-year contract at planned production rates. A turbulent funding history for a weapon system may suggest an unstable requirement, a relatively low funding priority, or wavering support; this may make the system inappropriate for multi-year contracting. Disagreements among the military services, OSD, and the Congress concerning the appropriate production rate and required funding for a system are often signals that funding is not stable.

Test and evaluation should be complete and demonstrate that the system, and therefore the design, is operationally effective. The Senate Committee on Appropriations, has always recommended that the multi-year approach be reserved for established production operations and state-of-the-art technology. Moreover, a program should be judged mature and stabie only after research and development and one or two production runs have been completed successfully.

Multi-year justification packages submitted to Congress often include estimates of industrial base enhancements that would result by applying the multi-year approach to any candidate weapon system. Examples of anticipated enhancements cited by the services include:

- Enhanced investment in infrastructure at the prime contractor and vendor levels
- Enhanced training programs
- Improved vendor skill levels
- Improved competition at vendor levels.

These enhancements then translate into increased production capacities and increased effectiveness.

The stability in contractor and subcontractor operation associated with multi-year contracts can create a level of business certainty more conducive to enhancing the industrial base than annual procurement. Nevertheless, it is difficult, if not impossible, to identify the industrial base enhancements that have occurred as a result of a multi-year contract that would not have occurred under annual contracts. No attempt to quantify a value for industrial base enhancements was applied during this analysis.

D. CASES EXAMINED

Short case studies were undertaken for a selected set of programs that have pursued an MYP acquisition strategy. We attempted to include all programs from the IDA database that were approved for MYP (see Table VI-2) and have at least two years of production experience under an MYP contract. Data were not available for the Patriot missile, TOW missile, Shillelagh projectile, and the Defense Satellite Program (DSP). The NAVSTAR Global Positioning System (GPS), the Defense Meteorological Support Program (DMSP), and the B-1B programs were not examined because all production contracts for these programs have been MYP. The programs we examined are listed below:

- Multiple Launch Rocket System (MLRS)
- UH-60 helicopter airframe
- CH-47 helicopter modification
- Defense Satellite Communications System (DSCS) III satellite
- F-16 aircraft.

Two additional MYP programs, the M1A1 tank chassis and the T700 engine programs, are not included in the IDA database, but were examined because data were available that contributed to this effort.

In each case the OSD MYP justification was reviewed to identify the circumstances existing in each program that led the services to claim that the following criteria for selection as an MYP program were met:

- Stability of requirement
- Stability of funding
- Stability of design
- Degree of cost confidence

No attempt was made to validate the estimated savings from multi-year contracts in DoD MYP Justifications [VI-2] provided to Congress. Nor were they used as data for this analysis. The estimated cost savings in the Justifications were simply taken to be the DoD position on the value of MYP. Not addressed here are micro-economic issues such as the appropriate size of (or even the requirement for) cancellation fees, present value issues, industrial base issues, and cross-program effects from use of an MYP strategy. These issues, while deserving of further study, are outside the scope of this effort. The focus of this analysis was strictly on whether MYP produces cost savings or contributes to the control of costs during the acquisition of a weapon system.

The case studies, found in Appendix C, present information from SARs, Contractor Cost Data Reports, and interviews with industry and program office staff. Production cost estimates were made for annual contracts corresponding to the years multi-year procurement actually occurred, where data were available. Appendix C presents the results of the comparison of MYP production costs and predicted costs under annual contracts.

E. ANALYSIS

We examined the programs in the IDA database that pursued a multi-year acquisition strategy, with a single objective: to show whether or not MYP had indeed contributed to production and total program cost savings. Very few of the programs in the IDA database exhibited absolute cost savings, where the current estimates of production and total program costs for the original procurement quantity are less than the original cost estimates. Because of this, we examined how MYP contributed to "cost savings" in the sense that these programs experienced significantly lower production and total program cost growth than other programs in the IDA data population. (MYP may not contribute to cost savings per se, but may contribute to the avoidance of cost growth experienced by programs pursuing other acquisition strategies.)

Two different sets of data from the IDA database of Selected Acquisition Reports were examined in order to identify benefits and costs of MYP. One set of data included 12 programs. The MYP programs from this data set, shown in Table VI-2, were selected from among the 73 programs in our database with production data because they had completed one or more multi-year procurement contracts. As is shown in Table VI-3, aggregate cost growth was less for MYP programs than for the general population of programs.

Table VI-2. Outcomes for MYP Programs

Systems	PCG	PSG	PQG	TPCG	STRETCH
UH-60A	1.25	1.00	1.00	1.22	1.00
NAVSTAR GPS	1.24	2.04	1.71	1.08	1.19
CH-47D	1.35	0.99	1.21	1.33	0.82
DMSP	0.92	1.00	1.13	0.95	0.89
Patriot	1.78	1.00	0.44	1.67	2.27
TOW	1.78	2.27	0.59	1.70	3.85
F-16	1.21	3.34	4.20	1.19	0.80
B-1B	0.95	1.00	1.00	0.95	1.00
MLRS	0.94	1.49	1.27	0.95	1.17
Shillelagh	1.51	1.44	0.89	1.45	1.62
DSP	1.00	1.20	1.47	1.06	0.82
DSCS III	1.75	1.17	1.08	1.99	1.08
Average Growth	1.31	1.50	1.33	1.30	1.38

Note: Cost growth figures are dollar-weighted.

Table VI-3. Cost and Schedule Outcomes of MYP Versus Non-MYP Programs

	MYP	Number of Programs	Non-MYP	Number of Programs
Production Cost Growth	1.31	12	1.62	51
Production Schedule Growth	1.50	12	1.62	45
Production Quantity Growth	1.33	12	1.18	51
Total Program Cost Growth	1.30	12	1.54	51

Note: Cost growth figures are dollar-weighted.

On average, MYP programs exhibited 31 percent lower cost growth in production and 24 percent lower total program cost growth. Regression analysis was used to develop equations relating production and total program costs, schedule growth, and quantity changes to the MYP initiative. Dollar costs were examined weighted and not weighted. None of the cost, schedule, or quantity models was significant.

The second set of data consisted of the same 12 MYP programs plus 12 MYP candidate programs. These 12 candidates had been rejected by Congress, or have only been recently approved for MYP funding. This set was examined to see if program stability, as measured by the criteria applied to MYP candidates, could be responsible for the lower cost growth observed in the approved MYP programs. Average measures of cost, schedule, and quantity growth are provided in Table VI-4 for the MYP candidate programs.

Table VI-4. Outcomes for MYP Candidates

Systems	PCG	PSG	PQG	TPCG	Stretch
Harpoon	1.64	3.05	0.95	1.53	3.21
Maverick	1.58	2.14	1.95	1.53	1.10
EA-6B	1.32	--	1.57	1.30	-
F-15	1.20	3.38	1.74	1.16	1.94
AV-8B	0.77	1.27	0.82	0.82	1.55
P-3C	1.35	0.80	0.48	1.42	1.67
Stinger	1.81	2.24	2.20	1.75	1.02
AH-64A	1.74	1.02	1.26	1.59	0.81
TOW 2	0.95	0.94	0.89	0.98	1.06
HARM	1.39	1.61	1.05	1.47	1.53
F/A-18	1.42	1.71	1.45	1.37	1.18
Improved Hawk	3.07	3.16	1.49	1.48	2.12
Average Growth	1.52	1.94	1.32	1.37	1.56
Without Hawk	1.38	1.82	1.31	1.36	1.51

Cost growth figures are dollar-weighted.

We examined and computed production and total program cost growth, schedule growth, and quantity change for approved MYP and candidate MYP programs. Production cost growth is 21 percent higher for the candidate sample than for the MYP sample. Total program cost growth differs by only 7 percent for MYP and candidate samples--1.30 and 1.37, respectively. Both samples exhibited cost growth lower than the averages for the population of all acquisition programs. Production schedule growth and program stretch are substantially larger for the candidates that were never approved for MYP.

If the Improved Hawk program, with its substantial cost growth experience (TPCG=3.07) is eliminated from the candidate sample, the difference in production cost growth between the two samples is 7 percent. The Improved Hawk program has involved a continuing series of major modifications to the 25-year-old Hawk system. Most of the modifications are to electronics of the fire-control radar, target acquisition systems, and missile guidance and control. These modifications have gone significantly beyond the scope of planned performance and production cost goals of the Hawk program. Multi-year contracting was proposed again for FY 1989 as a means to buy out remaining systems for the Marine Corps. This type of continued modification program is not typical of the major acquisition programs in our samples, and it is certainly not indicative of the contemporary programs that are considered for MYP. Therefore, Improved Hawk was eliminated from the sample of candidate programs.

Regression analysis was used, relating production and total program cost, schedule growth, and quantity changes to MYP. The sample was examined with and without Improved Hawk. Again, none of the models was significant.

We were not able in this macro-analysis to produce evidence that the multi-year contract was the principal contributor to the better-than-average cost growth of the set of 12 MYP programs. It is likely that multi-year contracting, along with the stability of the programs, contributed to the lower production cost growth of the MYP programs. However, it appears the larger percentage of production cost containment is due to the program stability factors, not to the effects of multi-year contracting.

F. FINDINGS AND RECOMMENDATIONS

The principal objective of multi-year contracting is to reduce procurement costs. OSD justifications indicate that the services expected to obtain savings of 10 to 20 percent when multi-year contracting is used. We conclude that although multi-year contracting can be considered successful, it is not likely to yield such large savings. Much of the cost savings that are attributed to multi-year contracting is more likely to be due to the criteria that are applied to multi-year candidates--stable system requirement, system design, program funding, and because of this program and stability, confidence in the production cost estimate--rather than to the implementation of the multi-year contracting strategy.

The twelve programs that have employed multi-year contracts exhibit lower production and total program cost growth than do the general population of programs examined during this study. Production cost growth is 31 percentage points lower for the multi-year programs, total program cost growth is 24 percentage points lower. Apparently, MYP also contributes to controlling production schedule slippage. Production schedule grow h is lower by 12 percentage points. However, we found no significant statistical relationship between use of multi-year contracting and production cost growth, total program cost growth, production schedule growth, and program stretch.

Multi-year programs do show improved outcomes when compared with other stable programs even though it is likely the MYP programs would have experienced better than average production and total program cost growth even if they had not been selected for multi-year contracting. We compared the multi-year programs with 12 programs that were rejected candidates for multi-year contracting. The acquisition outcome measures indicate that MYP programs performed slightly better than the candidates--a 7-percentage point difference in production cost growth and 6-percentage point difference in total program cost growth were exhibited.

We examined seven programs with completed or nearly completed multi-year contracts to evaluate price differences between multi-year and annual contacting. We computed unit prices for the multi-year contacts and then used the completed annual contracts for each program to estimate what the unit prices would have been under annual contracts. Our analysis indicated that some savings were present for MLRS, CH-47D, DSC III and T700 programs. Savings were not found for UH-60, F-16 and M1A1 tank chassis programs. In all cases, our analysis was limited by the fact that we could not isolate the unit price impacts of converting from annual to multi-year procurement from other factors that can cause unit price changes, such as production quantity changes, design changes, and system quality changes.

We recommend OSD continue support for multi-year procurement candidates. They should continue use of the present guidelines that call for evaluation of stability of the requirement, the system design, the funding plan, and realism of the cost estimate. Our examples clearly indicate that well-managed, stable programs can indeed benefit from MYP.

We also believe that OSD should study the possibility of relaxing the criteria by which multi-year candidates are evaluated, thus expanding the number of potential multi-year candidates. If the goal is to achieve savings of 20 percent with MYP, then savings of that magnitude can come only with the acceptance of increased risk by the government.

REFERENCES

[VI-1] Asbury, Clinton J., III. "A Program Manager's Guide on Multi-year Procurement." Report 86-0130, Air Command and Staff College, Air University.

[VI-2] Office of the Secretary of Defense. "Justification of Estimates for Fiscal Years 1988 and 1989 Submitted to Congress." January 1987.

[VI-3] U.S. General Accounting Office. "Procurement, Analysis of DoD's Fiscal Year 1986 Multi-year Candidates." Report to the Chairman, Subcommittee on Defense, Committee on Appropriations, U.S. Senate, November 1985.

[VI-4] U.S. General Accounting Office. "Procurement, Assessment of DoD's Current Multi-year Candidates." Briefing Report to the Chairman, Subcommittee on Defense, Committee on Appropriations, U.S. Senate, September 1986.

[VI-5] U.S. General Accounting Office. "Procurement, Assessment of DoD's Multi-year Contract Candidates." Briefing Report to the Chairman, Subcommittee on Defense, Committee on Appropriations, U.S. Senate, August 1987.

[VI-6] Utgoff, K, and D. Thaler. *The Economics of Multi-year Contracting*. Center for Naval Analyses Professional Paper 345, March 1982.

[VI-7] Utgoff, K, and D. Thaler. *Multi-year Procurement: The Perils of a Panacea*. Symposium paper, 18-20 May 1983.

VII. COMPETITION

A. BACKGROUND

Defense acquisition has a long history of competition. The Armed Services Procurement Act of 1947 required that contracts for property or services be formally advertised. OMB Circular A-109 directs that competition be used throughout a program, particularly during design and development. Competition at that point has the advantage of allowing the exploration of different alternatives. Competition often has been used in full-scale development. More recently, however, the government has emphasized competition in production, the explicit goal being lower prices and, possibly, better performance.

In the 1980s, Congress has prescribed production competition. In the Defense Appropriations Act of 1984, Congress required that any major acquisition program have either a certification that the system would be procured in insufficient quantities to warrant multiple sourcing or a plan for the development of two or more sources. The Competition in Contracting Act of 1984 established requirements for maximizing competition. Competition was to be the norm; exceptions were to be justified. CICA required the appointment of competition advocates to review acquisition strategies. It both provided for specific procedures designed to guarantee that all sellers could bid for a proposed procurement and established protest procedures. Additional legislation--the Department of Defense Procurement Reform Act and the Small Business and Federal Procurement Competition Enhancement Act of 1984 and the Defense Procurement Improvement Act of 1985--also aimed to increase competition in defense contracting.

In addition, the Defense Department has encouraged competition. The Defense Acquisition Improvement Program (the Carlucci Initiatives), instituted in 1981, includes an initiative to increase competition in the acquisition process. The Packard Commission recommended the use of commercial-style competition. It recommended development of a waiver before hardware could be uniquely developed for the military. In 1984, the Defense Systems Management College (DSMC) published a handbook for program managers on enhancing competition [VII-1].

Competition has a number of applications in defense procurement. We can think of the types of items that the government buys as being along a continuum with respect to quantity and complexity. Small, uncomplicated items that the government buys a lot of over the years are easy to compete. In many cases, these items are standardized, and it is relatively easy to obtain multiple sources. At the other end of the continuum, major weapons systems are developed on a customized basis and produced in relatively small numbers. A company that wants to produce Sidewinder missiles cannot merely do some quick tooling and start producing them--a detailed technical data package is needed.

In this study, we focused on competition as dual sourcing in production for major weapon systems and subsystems. This type of competition typically requires that the government have a hand in developing an alternative source, just as it developed the first source. Other methods of enhancing competition in major weapons systems, including vendor competition, are not discussed here.

B. BENEFITS AND WEAKNESSES

In the short term, the benefits of dual-source competition in major systems might be expected to include:

- Lower overall costs
- Increased contractor responsiveness to government needs
- Enhanced system quality and reliability, put in as an attractive feature for government purchasers. (A number of competition programs we studied, including Tomahawk and the alternative fighter engine, were motivated more by quality considerations than by cost.)

Longer-term benefits could include:

- Enhanced industrial base for particular systems
- Increased capital investment by contractors.

In the short term, the weaknesses of competition include additional costs in areas not found in single-source production:

- Competition typically requires an up-front investment for tooling, equipment, qualification, and administration to establish a second source.
- By splitting a buy between two contractors, the government may give up some economies of scale because the full benefits of learning and high-rate production are not realized. Large buys typically exhibit lower unit costs than small buys.

- If multiple configurations are required, support costs may increase.

There may be long-term weaknesses of competition with respect to the relationships between industry and the Department of Defense, but little attention has been paid these issues. Are the benefits of competition a one-time effect, or can they be sustained over time? Production competition in major systems must be viewed as an investment decision. The potential reduction in procurement costs must be weighed against additional up-front costs and increased government administrative costs. This tradeoff is unique for each program.

The DSMC program managers' handbook indicates a method for evaluating the impact of production-level competition on program costs. In evaluating potential or actual cases of competition, analysts may find these guidelines useful [VII-1, pp. 7-1, 7-2]:

(1) Estimate single source recurring production costs by fiscal year in constant dollars based upon progress curves and expressed as contractor price.

(2) Estimate competitive recurring production costs by fiscal year in constant dollars based upon progress curves. Reasonable assumptions must be made concerning shift and rotation and the second source progress curve.

(3) Calculate potential savings by subtracting (2) from (1) by fiscal year.

(4) Calculate net potential savings by subtracting annual incremental government costs, stated in constant dollars, from (3).

(5) Estimate nonrecurring start-up costs, stated in constant dollars, by fiscal year.

(6) Estimate incremental logistic support costs, stated in constant dollars, by fiscal year.

(7) Calculate a net present value of competitive versus sole source production costs by subtracting the discounted costs (5) and (6) from the discounted benefits (3).

(8) Compare discounted, constant, and then-year dollar estimates of single source and competitive production.

(9) Conduct detailed sensitivity analyses to investigate the effect of changes in key assumptions on the estimate of savings, and to develop a range of likely estimates.

C. TYPICAL APPLICATION

Competition can be applied in a variety of ways--so many that it is difficult to talk of a "typical" application. The examples that follow show that variety:

- In the sea-launched cruise missile (SLCM) program, the government required the contractors to fund the costs of technology transfer, but allowed them to charge back the amount at the rate of 1/1200 of the total cost for each of the first 1,500 missiles (*more* than they invested). However, the competition provided the contractors with a powerful incentive not to charge the full amount allowed.

- In the F100/110 alternative fighter engine program, the government funded the costs of bringing a partially developed engine to full capability. In the F404 engine competition, the government delivered an engine developed by one contractor for reverse engineering by another. The government and the second contractor made some up-front investment.
- In the High-Speed Antiradiation Missile (HARM) program, the government had a detailed technical data package from the first source, and three potential competitors invested in developing competing manufacturing methods for the design. (This program remained sole source.)
- In the Maverick missile program, the competition had a leader and a follower.

Government funding of the second source is fairly common, as is the use of "educational buys" or "qualification buys" to get the second source started. Another common factor is the use of annual competitive bids between contractors. Typically, in major systems, these annual competitions are not winner-take-all, but the buy is split between the contractors. This practice can cause the government some problems in fine-tuning its approach: the government must give the winner enough of a "reward" to encourage future low bids, but it must give the loser a large enough order to keep its production line going. Depending on how its bid is structured, a clever loser might end up with more profits than a winner.

D. CASES EXAMINED

To examine the evidence on competition, we gathered information on several programs from the database compiled for this study and from other studies on competition by IDA, Rand, and the services (particularly the Navy) [VI-2 through VII-19]. Among the many competition programs included in our review are the F100/110 and the F404 alternative fighter engines and the following missiles: Imaging Infrared (IIR) Maverick AGM-65D/F/G, Tomahawk ground-launched cruise missile (GLCM), Sparrow AIM-7F and AIM-7M, HARM, Hellfire, TOW (tube-launched, optically tracked, wire-guided), Sidewinder AIM-9L and AIM-9M, Phoenix, basic Stinger, Shillelagh, and Dragon. The analysis of the data gathered is described in the next subsection.

Further information on the following programs are contained in the case studies in Appendix D: the alternative fighter engines, HARM, Sparrow AIM-7F, IIR Maverick, Tomahawk, and Hellfire.

E. ANALYSIS

Depending on the appropriateness and availability of data, we conducted the following analyses:

- Analysis of data on price and quantity, on the number of competitive years, and on the startup costs of the competition, for programs which we had the cooperation of one or both contractors and relevant program offices
- Analysis of the costs and benefits of competition
- Analysis of the program database described in Section III, including statistical analysis of cost growth estimates.

Our examination of individual cases yielded the following results:

- In the F100/110 alternative fighter engine competition, the evidence on savings is confounded by a model change. However, since a model change (which normally is costly) was achieved without a statistically significant increase in price, a reasonable interpretation is that competition has had a favorable impact on unit prices. In the F404 engine, savings of $125 million to $300 million were found in our analysis.
- In the IIR Maverick program, competition has so far resulted in increased costs. However, it is possible that the government will achieve savings if it continues to acquire these missiles through FY 1997 as planned.
- In the Sparrow AIM-7F program, other research (including an independent evaluation of work by the Naval Center for Cost Analysis (NCA) [VII-2, VII-6]) found no evidence of savings. Our own analysis also found no evidence of savings.
- In the Tomahawk missile program, both the program office and the NCA show cost savings over sole source.
- In the HARM program, lower prices from the threat of competition resulted in a decision not to dual source. Incumbent Texas Instruments dropped its price by $209 million for the period FY 1983-85 and by $1.2 billion for the period FY 1983-89 in order to stay sole source [VII-8].
- In the Hellfire program, there is no evidence of savings from competition. However, a second source was established at no apparent cost to the government.

In addition to the case studies, we reviewed several studies of dual-source programs. The results of this review are summarized below:

- Berg, et al. [VII-7] found an unclear picture with respect to the Sparrow AIM-7F competition as to whether there were savings or not. They found no savings in the Sidewinder AIM-9L competition, but savings of about 11-12 percent were found in the AIM-9M competition.

- The behavioral aspects of competition--the effects of competition on the way contractors do business--are very important. Relatively few sources discuss these aspects of company strategy. Greer and Liao [VII-17] cite three alternative strategies a firm may pursue in response to competition. These include:

  - Constant percentage profit
  - Penetration pricing--first source sets price low enough to discourage competition
  - Skimming price--company sets a high price and lowers it as necessary to meet competition.

  Greer and Liao use industry capacity utilization as a measure of what strategy companies are likely to follow. If capacity utilization is high, then firms are busy and are unlikely to lower prices very far to get work. However, if capacity utilization is low, firms are willing to be very flexible about price in order to keep working. We believe that more analysis of this type is warranted.

- In 1987, the NCA examined eight cases of competition for cost savings [VII-2]. They found that five of the eight programs (Sidewinder AIM-9L, armored box launcher, CG-47 cruiser, LSD-41 landing ship dock, and Mk 182-1 chaff cartridge) had associated net price savings, or at worst, an approximate breakeven. Net savings estimates ranged from 4-24 percent of estimated total sole-source price. Two programs (Mk 46 Mod 1 and AIM-9M) had a net price loss. AIM-7F had savings if Lot 3 is the assumed start of competition, but a loss if Lot 5 is the assumed start.

- Berg, Jondrow, and Pisani [VII-3] used a pooled sample of 18 missile programs over the period 1970-84. They found that competition had a negative effect on cost, but it was not generally statistically significant.

- A study of financial strength as a predictor of pricing strategy (Webb [VII-14]) found that a significant portion of the variance in the price-reduction curve could be explained by the firm's financial condition measured against industry averages. While Webb was looking primarily at sole-source programs or at vendors, the results are interesting to contemplate in the light of competitive strategies. Firms that are investing most heavily in new plants and equipment are motivated to adopt market penetration strategies (e.g., work to build market share) to ensure that their capacity will be used. Firms with poor liquidity will prefer profits in the near term and may go after small but profitable pieces of the market. We have seen evidence of such behavior under competition, although we have been unable to correlate it with financial position. For example, McDonnell Douglas built the Titusville plant exclusively for Tomahawk missile production, and they have bid aggressively to win quantity. Conversely, Raytheon seems to be becoming a specialist in being a follower, a production specialist.

Table VII-1 shows results from the aggregate analysis. As indicated in Section V, none of the regression estimates was statistically significant. However, an analysis of averages from the full sample and from the group of tactical munitions (where virtually all the competition in our group of programs has occurred) is interesting. In the full sample, cost growth under competition is higher. However, cost growth under competition is lower among the tactical munitions, where most of the competition has occurred.

Table VII-1. Comparison of Outcomes for Competitive and Non-Competitive Programs

	Full Sample		Tactical Munitions	
	Competitive (N = 13)	Non-Competitive (N = 51)	Competitive (N = 11)	Non-Competitive (N = 17)
TPCG	1.74 (12)	1.49	1.78	2.16 (16)
PCG	1.78 (12)	1.64	1.82	2.46 (16)
PQG	1.90 (12)	1.06	1.74	0.78 (16)
PSG	2.12 (12)	1.53 (45)	2.19	1.60 (15)
Stretch	1.65 (12)	2.01[a] (44)	1.76	3.15[a] (15)
PS[b]	129.0 (12)	126.6 (44)	131.2	117.1 (15)
TS[c]	193.6 (12)	167.4 (43)	193.0	169.6 (15)
DCG	1.77	1.24 (55)	1.88	1.42
DSG	1.81	1.27 (56)	1.89	1.42
CS[d]	34.5	32.2 (49)	34.1	30.4

[a]Condor (stretch = 56) excluded.
[b]PS = production schedule (months).
[c]TS = total schedule (months).
[d]CS = concurrent schedule (months).

Notes: The competitive tactical munitions programs are TOW, Hellfire, Sparrow AIM-7F and AIM-7M, Sidewinder AIM-9L and AIM-9M, Maverick AGM-65D, Phoenix AIM-54A and AIM-54C, Basic Stinger, Shillelagh, and Dragon. The only competitive programs in the database that were not tactical munitions were the electronic systems Sincgars (which had only development information) and the cruise missile Tomahawk. Cost growth figures are dollar-weighted. Figures in parentheses are numbers of programs for cells with missing data.

In both cases, production quantity growth is much higher in the competitive programs, and program stretch is much lower. Possible explanations are that stable programs are chosen for competition, or that the government keeps competitive programs more stable, given its up-front investment to dual source.

F. FINDINGS AND RECOMMENDATIONS

The findings of our analyses of competition programs are summarized below:

- In missile programs, cost growth in competitive programs was lower than in non-competitive programs. While this difference was not statistically significant, it suggests that competition may be beneficial.
- Findings about competition in the case studies are sensitive to assumptions about what prices would have been if the program had remained sole source. The literature on cost savings is contradictory.
- It is easier to find savings in prices than in costs. Several studies evaluating costs such as engineering hours and manufacturing hours find similar direct costs in competitive and sole-source programs. Thus, savings from competition seem to come out of profits, as theory would expect. It makes sense to look for savings in programs where profits have historically been high.
- Competitive programs tend to buy more quantity than planned over a longer period of time than planned. This tends to amortize development costs and second-source startup costs. It may be that the benefits seen from competition are really benefits of program stability--this is a chicken-egg problem.
- Cross-program effects and industry strategies have been insufficiently analyzed. Even if we see savings from competition, we also need to examine whether there are cost increases in sole-source programs produced in the same plant. Also, in some programs, such as Hellfire, we see a seesaw pattern of production, with the companies taking turns winning the major share of the year's production. We need to consider whether this is being used as a device to plan stable production rates. One-shot gains may be possible as competition represents a shock to the system--it is unclear that such gains can be sustained if competition becomes a universal acquisition strategy.

These findings pertain to major systems. For subsystems, the competition picture is quite different. Up-front investments are typically smaller, the number of items being procured is often larger, and the items are frequently less complicated.

Based on our findings, we can make the following recommendations as concerns dual-source competition in major systems:

- Dual-source production should not be prescribed across the board for major systems. Competition can be of value in particular individual cases; however, it is very difficult to predict what those cases are. Additional work needs to be done on criteria for competition. It should not be universally applied. The larger and more customized the system, and the lower the quantity, the harder it is for competition to be viable because of the larger investment.

- That cost savings from competition are uncertain should be recognized. It does not make sense to plan on large, immediate cost savings. Competition requires some up-front investment, and payback is over a number of years.

- Specific guidelines should be established for competition, similar to those for MYP. Competition is best applied under the following conditions:

  - A large number of systems are required
  - A firm plan and stable funding are available
  - Break-even analysis suggests that costs can be recovered over reasonable period.
  - Technology transfer involved is relatively straightforward
  - Adverse effects on other programs are negligible.

- Benefits other than reduced prices may exist and need to be considered. Among these are increased contractor responsiveness, increased system reliability, and preservation of the industrial base

- Additional research should be done into the long-term effects of competition. Such research should go beyond the individual program to consider overall contractor strategies.

REFERENCES

[VII-1] Defense Systems Management College. "Establishing Competitive Production Sources: A Handbook for Program Managers." August 1984.

[VII-2] Naval Center for Cost Analysis. "The Effect of Competition on Procurement Price." December 1987.

[VII-3] Berg, Robert M., James M., Jondrow, and Albert A. Pisani. *An Exploration of the Statistical Determinants of Tactical Missile Prices*: Results Based on Aggregate Data. Center for Naval Analyses, CRM-87-187, October 1987.

[VII-4] Birkler, John L., and Joseph P. Large. *A Closer Look at Second-Source Procurement*. Rand Corporation, briefing, April 1987.

[VII-5] Kish, Ernest J. "Containing Weapon Program Costs in a Sole-Source Environment." *Program Manager*, vol. 15, no. 2 (March/April 1986).

[VII-6] Beltramo, Michael N., and David W. Jordan. "A Brief Review of Theory, Analytical Methodology, Data, and Studies Related to Dual Source Competition in the Procurement of Weapon Systems." Preliminary Report, August 1982.

[VII-7] Berg, Robert M., et al. *Case Studies on the Use of Competition in the Sidewinder and Sparrow Missile Programs*. Center for Naval Analyses, CRM 87-126, July 1987.

[VII-8] Merrimack Associates. *A Synthesis of Case Studies in Production Competition*. Spring 1987.

[VII-9] Zusman, M., et al. *A Quantitative Examination of Cost-Quantity Relationships, Competition during Reprocurement, and Military vs. Commercial Prices for Three Types of Vehicles*. Institute for Defense Analyses, Study S-429, March 1974.

[VII-10] Lovett, E. T., and M. G. Norton. "Determining and Forecasting Savings from Competing Previously Sole Source Contracts." Army Procurement Research Office, APRO 709-3, October 1978.

[VII-11] Daly, G. G., H. P. Gates, and J. A. Schuttinga. *The Effect of Price Competition on Weapon Systems Acquisition Costs*. Institute for Defense Analyses, September 1979.

[VII-12] Archibald, K. A., et al. "Factors Affecting the Use of Competition in Weapon System Acquisition." Rand Corporation, R-2706-DR&E, February 1981.

[VII-13] Beltramo, Michael N., Richard B. Collins II, and Lisa Olshan. "The Effect of Competition on Procurement Cost: Analysis of Ten NCA Case Studies." Science Applications International Corporation, February 1987.

[VII-14] Webb, Paul B. "Financial Strength as a Predictor of Pricing Strategy." Thesis, Naval Postgraduate School, December 1987.

[VII-15] Burnett, William B. "Competition in the Weapons Acquisition Process: The Case of U.S. Warplanes." *Journal of Policy Analysis and Management,* vol. 7, no. 1. (1987), pp. 17-39.

[VII-16] Berg, Robert M., Richard L. Dennis, and James M. Jondrow. *Evaluation of Models and Techniques for Estimating the Effects of Competition.* Center for Naval Analyses, CRM 86-15, January 1986.

[VII-17] Greer, Willis R., and Shu S. Liao. "An Analysis of Risk and Return in the Defense Market: Its Impact on Weapon System Competition." *Management Science*, vol. 32, No.10, October 1986.

[VII-18] Berg, Robert M., R. Dennis, and J. Jondrow. *Price Analysis and the Effects of Competition.* Center for Naval Analyses, Professional Paper 442, October 1985.

[VII-19] Miller, Bruce M., and Paul R. Palmer. *Acquisition of Contemporary Tactical Munitions,Vol. 2: Case Studies.* Institute for Defense Analysis, Paper P-2173, forthcoming.

VIII. PROTOTYPING

A. BACKGROUND

Prototyping has been practiced in some form or other throughout the history of warfare. There has always been a need to test new types of equipment before any large-scale application. Since the end of World War II and the advent of the systems management approach to defense weapons acquisition, prototyping has become a part of the weapons acquisition process. During this period, it has endured cycles of popularity and disfavor and many advantages and disadvantages have been cited. This section addresses the issue of prototyping using quantitative evidence where available for prototype and non-prototype programs.

As defined in this study, prototyping refers to the construction and testing of working models created to demonstrate specific design or operational objectives in advanced development (but not in concept exploration)--e.g., before full scale development (FSD) (Milestone II). Our definition does not include FSD test articles. The primary objective of any prototype program is to obtain information to reduce the uncertainty and risk concerning the design concept, cost, or usefulness of a particular model prior to initiation of full scale development (and production). Thus, prototyping intends to buy information at a relatively modest cost in dollars and in time in order to determine if the particular design configuration can or cannot meet the objectives specified for it. Either a positive or negative outcome can be worthwhile in that an unsuccessful outcome will preclude going down the wrong design path during full scale development, when much higher levels of resources are being obligated to the program.

The functional objectives of prototyping are not always clearly delineated in a program. In this study, the objectives of prototyping are to:

- Provide proof of concept
- Provide proof of system/subsystem performance (and cost)
- Provide proof of operational suitability.

B. BENEFITS AND WEAKNESSES

The benefits and weaknesses of prototyping can vary widely, depending upon the program, the information to be gained from prototyping, and the cost to obtain that information. In general, weaknesses include the additional resources and time needed to accomplish a prototype prior to FSD start. The benefits are postulated to include lower costs in FSD and production and shorter time in FSD. These might occur due to the information gained from prototyping, which results in fewer changes in FSD. A hypothesis of this study is that prototyping does hold down cost growth in development and production.

For the tactical aircraft programs noted above, prototyping slightly increased program acquisition costs. The YF-16 prototype cost on the order of $100 million in a $30 billion program; in the case of the A-10, about $100 million in a $5 billion program, and for the AV-8B, $150 million for a $10 billion program. The cost ranges around a few percent of the total program. This seems to be the range for other types of equipment as well. This is a reasonable price to pay for the information if there is some technical or operational uncertainty.

Prototyping should not be applied where it does not look like the information to be gained will be useful to the accomplishment of the program. This can be a difficult decision. A clear example here is the aircraft nuclear propulsion program in the 1950s. The uncertainty had to do with the aircraft nuclear reactor performance, weight, and cost, and yet a great deal of time and money went into building the large turbine engine that was going to be driven by the nuclear reactor even though the components of the turbine engine were well-understood. It is estimated that an additional $500 million was spent on the aircraft nuclear propulsion program because the X-211 turbine engine was built and tested when there were still substantial technical and cost risks for the reactor. The program was eventually cancelled because of the technical problems and costs associated with the nuclear reactor. The X-211 did not contribute a great deal to advancing the turbine engine state-of-the-art. This example highlights the need for sound judgment to select appropriate prototypes, at the subsystem level as well as at the system level.

C. TYPICAL APPLICATION

Prototyping may be accomplished at the system or subsystem level. It may be used during concept exploration to achieve a proof of concept, or during advanced development to achieve a proof of performance, cost, or operational suitability. An example at the system level of proof of concept would be a new V/STOL aircraft design approach such as the tilt-wing, fan-in-wing, or thrust-augmentation concepts. At the subsystem level, examples are the advanced turbine engine gas generator (ATEGG) and aircraft propulsion system integration (APSI) demonstrator programs for new aircraft turbine engine designs. Examples of proof of performance or cost might include the F100 engine competitive demonstration and the APG-63 radar competitive demonstration prior to the F-15 FSD start. Examples of proof of operational suitability include the YA-10, YF-16, and YAV-8B tactical aircraft, where certain features of the aircraft were being demonstrated, but emphasis was also on the ability of the aircraft to perform a useful operational mission. Operational prototypes can continue to be useful after full scale development begins in that they can accomplish certain testing before full scale development test articles are available.

D. CASES EXAMINED

Three different sets of data were examined in order to identify benefits and costs of prototyping. One set of data was from Selected Acquisition Reports (SARs) for 36 programs, 19 of which were prototypes and 17, non-prototypes, as shown in Table VIII-1. A second set consisted of 9 tactical aircraft programs containing 3 prototype and 6 non-prototype programs, as shown in Table VIII-2. The third set consisted of 19 tactical munitions programs containing 10 prototype and 9 non-prototype programs, as shown in Table VIII-3.

Table VIII-1. Selected Acquisition Reports Database

Prototype Programs	Non-Prototype Programs
A-10	F-14A
F-16	F-15
F/A-18	S-3A
F-5E	E-4
AV-8B	EA-6B
E-3A	E-2C
LAMPS Mk III	EF-111A
E-6A	C-5A
B-1B	Mk-48
AH-64A	Lance
UH-60A	Patriot
Harpoon	Stinger-Basic
HARM	Shillelagh
Phoenix A	Dragon
TOW	Pershing II
Hellfire	SRAM
MLRS	Peacekeeper
ALCM	
Copperhead	

Table VIII-2. Tactical Aircraft Database

Prototype Programs	Non-Prototype Programs
F-16	F-4
A-10	F-14
AV-8B	F-15
	F/A-18
	F-111
	S-3

Table VIII-3. Tactical Munitions Database

Prototype Programs	Non-Prototype Programs
Phoenix A	Stinger-POST
AMRAAM	Stinger-RMP
HARM	Semi-Active Laser GP
Harpoon	Sparrow AIM-7E
Hellfire	Sparrow AIM-7F
TOW	Sidewinder AIM-9L
Sparrow AIM-7M	Sidewinder AIM-9M
Maverick D	Phoenix AIM-54C
MLRS	TOW 2
CLGP	

E. ANALYSIS

We examined and compared development cost, schedule, production cost, and total program cost growth for prototype and non-prototype programs in the three databases.

1. Analysis of SAR Data

The database for the SAR programs had the following restrictions:

- New starts or significantly different modification programs only (all follow-on modification programs were removed)
- No electronics programs
- No satellite programs
- No immature programs (at least five years of production data as of FY 1988)
- No canceled programs.

We exercised some judgment in selecting this database. We include the EA-6B and the E-2C in the non-prototype programs because they were very different from their predecessors. Similarly, the EF-111A is included since it was basically an electronics modification for a different mission. The AV-8B was significantly different from its predecessor programs, which is why it required a prototype. In the case of electronics, we had difficulty in obtaining production costs. We believe that one of the primary reasons for prototyping is to get information that will help to hold down production costs. Similarly, we do not think that satellites undergo prototyping by our definition because the satellites that get launched are expected to work from the start. For similar reasons to the electronics, we did not include immature or canceled programs. We wanted a full range of development and production costs to explore.

The results of the analysis of SAR data are presented in Table VIII-4. Equations were obtained for the 36 data points when the dollar costs were weighted and not weighted. For the non-weighted cases, prototyping results in significantly less cost growth for development, production, and total program. None of the schedule or quantity models was significant. For development cost growth, prototyping resulted in an 17-percent reduction; for production cost growth, the model indicates a 26-percent reduction; and approximately a 19-percent reduction in total program cost growth. These models were significant at the 10-percent level.

Table VIII-4. Effect of Prototyping on Cost Growth

Non-Dollar-Weighted		
DCG	=	1.473 – 0.25 (PROTO)[b] (–1.99)
PCG	=	1.775 0.466 (PROTO)[b] (–1.76)
TPCG	=	1.582 – 0.298 (PROTO)[b] (–1.88)
Dollar-Weighted		
PCG	=	1.619 – 0.335 (PROTO)[a] (–2.08)
TPCG	=	1.472 –0.215 (PROTO)[b] (1.83)

[a]Significant at .05 level.
[b]Significant at .10 level.

When the database was analyzed using a dollar-weighted set of data, development cost growth, development schedule growth, and development quantity growth were not significant. Production cost growth decreased by 21 percent, and total program cost growth decreased by 15 percent. Prototyping had the effect of lowering cost growth in development, production, and the total program on the order of 15 to 25 percent.

2. Analysis of Selected Tactical Aircraft Data

We examined nine tactical aircraft programs as to the impact that prototyping had on schedule length, including the advanced development period, FSD start to first flight period, and FSD start to 24th unit delivery period. We considered the F/A-18 a non-prototype program (see Table VIII-2) because of the extensive changes in the Air Force prototype design that resulted in the Navy FSD design.

When comparing a paper study competition to a prototype hardware competition, time is added to the overall length of the development as defined from start of advanced development through IOC. The hardware competition might add an additional one to two years, but the additional total time, development to IOC, would be on the order of perhaps 15 to 20 percent.

The results of the analyses for the three time periods are presented in Table VIII-5. The first equation indicates that prototyping increases time in the pre-FSD period by 19.33 months, more than doubling it. However, time to first flight (in the second equation) is reduced by 2.7 months. Overall FSD time (third equation) is around 11 percent less with prototyping.[1]

Evidence shows that the prototyping experience reduces time in FSD, because the prototype can be used early in FSD, prior to the availability of development test articles, helping to gain information early in the program. Thus, the cost and time penalties associated with prototyping are not necessarily as large as might be assumed by simply adding a prototype program on top of an FSD program. Gaining information and choosing attractive options while precluding unattractive options can particularly benefit complex high-cost programs. The evidence from examination of tactical aircraft schedules and cost bears this out with an 11-percent reduction of FSD time (resulting in an overall schedule

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1 The overall FSD equation was run using a multiplicative specification:

$$T24 = b1 * A^{b2} * e^{(COMPANY*b3)} * e^{(PROTO*b4)}.$$

In order to interpret the results more easily, the parameters associated with the two dummy variables (b3 and b4) were converted from exponents to multipliers. Thus, prototyping is associated with an overall FSD time that is 89 percent of the FSD time without prototyping.

increase of 15 percent from start of advanced development to delivery of the 24th aircraft), a reduction of FSD costs, and less production cost growth when the aircraft reaches production. Lower cost growth might be attributed to fewer changes in FSD because of the earlier prototype information.

Table VIII-5. Effect of Prototyping on Development Schedule Periods

Pre-FSD Period

$$PFSD = \underset{(.0002)}{13.0} + \underset{(.0005)}{19.33}\,(PROTO)$$

$N = 9$; $R^2 = .84$; ADJ $R^2 = .81$; SEC = 4.55

Time to First Flight Period

$$TFF = \underset{(.0001)}{25.1} + \underset{(.002)}{6.9}\,(COMPANY) - \underset{(.065)}{2.7}\,(PROTO) + \underset{(.060)}{2.9}\,(TEAM)$$

$N = 9$; $R^2 = .93$; ADJ $R^2 = .89$; SEE = 1.6

Overall FSD Period

$$T24 = \underset{(.0011)}{22.1}\,(A)^{\underset{(.054)}{-.141}} \times \underset{(.035)}{1.15}\,(COMPANY) \times \underset{(.075)}{.89}\,(PROTO)$$

$N = 8$; $R^2 = .95$; ADJ $R^2 = .91$; SEE = .05

Source: Reference [VIII-1].
Note: Significance levels are in parentheses.

3. Analysis of Selected Tactical Munitions Data

The tactical munitions data (see Table VIII-3) were analyzed concerning program outcomes that included development cost, schedule, and quantity growth; and production cost growth. Non-parametric statistical tests were applied to determine if prototyping had a significant effect on the program outcomes. The results are shown in Table VIII-6.

Table VIII-6. Effect of Prototyping on Program Outcomes in Tactical Munitions

Program Outcome	Advanced Development Prototyping (Significance–Mann-Whitney Test)
Development Cost Growth	Significantly lower
Development Schedule Growth	Not significant
Development Quantity Growth	Significantly lower
Production Cost Growth	Not significant

Source: Reference [VIII-2].

The analysis of tactical munitions indicates that prototyping had an effect on reducing development cost growth and development quantity growth, but no impact on production cost growth.

F. FINDINGS AND RECOMMENDATIONS

Results varied based on data analyzed, but were always in the same direction--prototyping helped improve program outcomes. The evidence indicates that prototyping is a successful initiative when used appropriately. It should be pursued vigorously where significant information is to be gained and the prototype represents only a small percentage of acquisition costs. It should certainly be applied in advanced development for systems and critical subsystems and can also be used successfully before advanced development in concept exploration, both at a system level and at a subsystem level. Specific guidelines should be established for determining appropriate applications. The guidelines should provide bounds to costs for the benefits to be expected from a particular application. For instance, no more than 2-3 percent of total acquisition cost should be spent for advanced development prototypes.

REFERENCES

[VIII-1] Harmon, Bruce R., Lisa M. Ward, and Paul R. Palmer. *Assessing Acquisition Schedules for Tactical Aircraft.* Institute for Defense Analyses, Paper P-2105, February 1989.

[VIII-2] Gogerty, C. D., et al. *Acquisition of Contemporary Tactical Munitions, Vol. 1: Summary Report.* Institute for Defense Analyses, Paper P-2173, forthcoming.

IX. DESIGN-TO-COST

A. BACKGROUND

The design-to-cost (DTC) concept was instituted as one of several reforms to Department of Defense (DoD) procurement practices. Developed primarily by former Deputy Secretary of Defense David Packard and by former Director of Defense Research and Engineering (DDR&E) John Foster, DTC was an initiative designed to develop a unit cost goal early in the design process. DoD Directive 4245.3 of April 6, 1983 defines DTC as:

> an acquisition management technique to achieve defense system designs that meet stated cost requirements. Cost is addressed on a continuing basis as part of a system's development and production process. The technique embodies early establishment of realistic but rigorous cost goals, and thresholds and a determined effort to achieve them.

The DTC goal is initially expressed in terms of the average unit flyaway (or rollaway or sailaway) cost associated with an end item of military hardware. As the ability to translate operations and support cost elements into "design to" requirements improves, DTC goals and thresholds are related to total life-cycle cost (LCC).

On 13 July 1971, DTC became official policy in DoD Directive 5000.1. The Directive provides that system development be "continuously evaluated against these (design-to) requirements with the same vigor as that applied to technical requirements." On 18 June 1973, Deputy Secretary of Defense Clements issued a memorandum entitled "Design to a Cost Objectives on DSARC Programs," directing that a DTC goal be applied to all major DSARC programs. At this point the concept moved from being a goal (in DoD Directive 5000.1) to being a requirement for all major programs in the acquisition process. In October 1973, two documents on methodology for DTC were released: (1) "Joint Design to Cost Guide" dated 3 October 1973 and (2) "Cost to Produce Handbook," dated 26 October 1973. Further refinement of the concept occurred in 1974.

In 1975, DoD Directive 5000.28 was issued imposing the concept of DTC on all major systems acquisitions, requiring that cost be weighted equally with performance and schedule. According to DoD Directive 5000.28 (1973), DTC has a twofold objective, as described below:

- To establish cost as a design parameter equal in importance to technical requirements and schedules throughout the design, development, production, and operation of the system.
- To establish cost elements as management goals for acquisition managers and contractors to achieve the best balance among LCC, acceptable performance, and schedule [IX-1].

B. BENEFITS AND WEAKNESSES

The primary benefit of DTC is the ability to estimate costs throughout the system's life cycle. Additional benefits are:

- DTC defines a measurable design parameter to be evaluated along with performance. A DTC parameter may be a goal or a threshold; values can be expressed in constant dollars, resources required, or other measurable factors that influence cost [IX-2].
- DTC provides a basis for communication and coordination of effort between government and industry participants. The cost goals can serve as a "contract" between the program manager and the OSD for major programs or the services for smaller projects [IX-2].
- DTC leads designers and production engineers to take a design/production team approach during the design process. This means that the final design is one that is compatible with production capabilities without extensive modification of production facilities. The net effect is reduced costs. For example, the A-10 effort by Fairchild incorporated the design/production team approach and produced its prototype in a configuration very close to the production model.
- DTC may provide easier maintainability through simplicity of design. Having to meet definitive cost goals will cause the designer to look for the simpler design, which reduces production costs, but which may also reduce maintenance time and cost in field operation.
- DTC causes better definition of performance requirements. This means that the requirements that are identified are the crucial ones for the system.
- DTC identifies specifications in minimum terms of performance, thereby providing the contractor with leverage to make cost-effective tradeoffs.
- DTC can result in reduced operating and support costs, because of flexibility and simple designs.

- DTC provides strong motivation to restrain cost growth. Managers are reluctant to have to justify cost increases without good reasons. Likewise, contractors with incentives based on a specific cost goal will be hesitant to break through a cost ceiling knowing that it will cost them in profits.
- DTC can provide an early idea as to whether or not cost objectives will be met. When a manager is working with a constrained budget, or when production is based on projected cost, it is important to know early in the process if the designated goal can be achieved. DTC can do this because it tracks total system costs and can detect unsatisfactory trends early in the program.
- DTC can lead to more standardized components, thereby providing the potential for significantly reducing costs.

In spite of all the expected benefits, the DTC concept also has some weaknesses. These are explained below [IX-3]:

- DTC may result in cost goals being established too early. DTC forces the program manager to commit to a DTC goal well before final agreement on configuration and operational requirements. Hence, the need to "sell" the program may drive DTC goals down to unrealistic levels. The key to the success of the DTC concept is the early determination of a specific cost goal; however, it may be extremely difficult to maintain a goal established so early in development. Tradeoffs are made. Test results may change the direction of the development. Reassessment of the threat may alter program direction. Environmental restrictions could alter the development of the system. Planned production rates may change in response to the results of initial tests. All of these items could drastically affect a goal based on a paper assessment. So one of the cornerstones of DTC itself represents a significant weakness of the concept.
- DTC may stifle innovation and restrict the use of new technology. A contractor with a specified cost goal tends to use what works, rather than trying a new approach that may reduce costs but involves risk.
- DTC could cause suboptimization. The short-term goal of meeting a specific cost ceiling may cause decisions that ignore long-term cost effects. When budget dollars and schedules are constrained, it is easy to ignore potential deficiencies because they will not be a problem for several budget periods, and then they will be someone else's problem.
- DTC results in performance buy-in. The contractor might promise superior performance at the DTC goal, but then fail to match his claims with results after getting the contract. This problem can be partially eliminated through the use of contractor "flyoffs" or prototypes to determine how well promises match results.

- DTC reduces versatility. This may be caused by failure to include versatility in the system because it adds to cost. The existence of the DTC program could tend to inhibit tailoring and innovation.
- DTC imposes factory cost goals that are too detailed. If goals are established at levels too specific, the benefits of DTC in contractor flexibility and cost control might be adversely affected. The more that is specified, the less flexibility the contractor has in meeting cost objectives.
- DTC may increase development costs. The concept requires sufficient development time and money to be used successfully.
- DTC requires additional people, time, and effort to plan and execute the program.

C. TYPICAL APPLICATION

DoD Directive 4245.3 requires the DTC goal to be established before Milestone I or at the earliest practical date thereafter, but in no case should the goal be established later than entry into FSD. Figure IX-1 illustrates DTC in the acquisition life cycle.

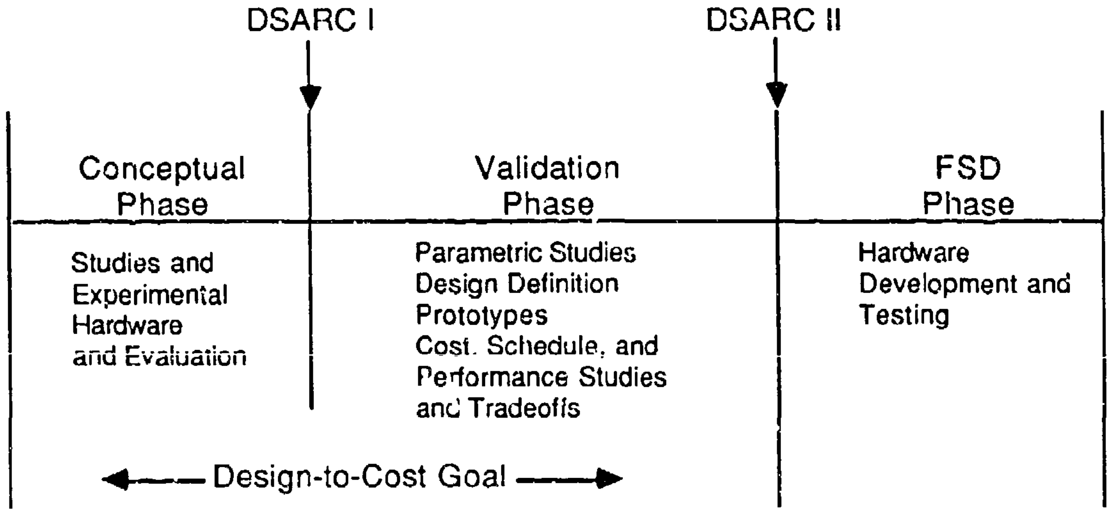


Figure IX-1. Design-to-Cost in the Acquisition Life Cycle

The staff of the Directorate for Procurement Policy examined over 35 contracts that used the DTC concept and found that about 40 percent had the DTC requirements implemented after the contract was executed [IX-4]. For example, the DTC goal for the F/A-18 was implemented after the program entered the FSD phase. In general, the DTC concept has not been properly applied. It has not been implemented early enough in the concept formulation phase, when greater flexibility existed to maximize total performance for the dollars available. In most programs, the DTC goal was not followed through to completion. It either was dropped or faded away in program FSD (F/A-18).

The following are guidelines for successful use of DTC:

- Early DTC goal establishment. The goal must be established before the start of the validation phase, because it provides a baseline to work against in the tradeoff decisions, which occur during validation.
- Design flexibility. The number of specified performance parameters should be minimized in DTC. They should also be ranked according to priority, if possible.
- Use of new technology to lower cost rather than to increase performance. This requires a change on the part of engineers who for years have been encouraged to rank performance over cost.
- Cost estimating. The DTC goal should be allocated down the work breakdown structure and tracked regularly for both prime contractor and subcontractor efforts. The DTC goal should be related to quantity from Unit 1 on up; setting a DTC goal for Unit 1 imposes strict discipline on the designer and permits an early indication of compliance.
- Contractual incentives. Contractual innovations are needed to give the contractor an incentive to build a reliable, low-cost product. Reliability Improvement Warranties and award fees are two such devices.
- Availability of time and money. DTC should require that adequate time and sufficient funds are available during development to permit examination of tradeoffs and alternative design approaches. Constraining either may cause suboptimization.
- Realistic cost objectives. The goal should reflect the best estimate based on available data.
- Cost tracking. This will permit periodic determination that the system can still be produced within the pre-established goal. It provides a methodology to spot problem areas early enough to take corrective action. It also provides a historical record of what happened during the process.
- Constant-year-dollar cost goals. Expressing the cost goals in constant-year dollars provides a baseline to measure costs against, even with inflation affecting the value of future-year dollars.

D. CASES EXAMINED

The following cases illustrate the application of DTC in three systems, the F/A-18, the A-10, and the AH-64. Due to the relative availability of data, the cases presented vary considerably in scope and detail.

1. F/A-18 Aircraft

The F/A-18 program called for 11 RDT&E and 800 production aircraft. DTC was introduced as a requirement in the FSD contract awarded to McDonnell Douglas in January 1976. The contract also included a DTC incentive clause that provided for adjustments in FSD earnings for variations in cost from the DTC goals set down in the contract. In December 1978, production quantity was increased from 800 to 1,366, then was reduced to 1,157 in 1986. The F/A-18 has been significantly upgraded since its inception as a "low-cost" fighter.

The DTC goal was based on a cumulative average recurring cost for 800 aircraft. Changes in program plan and schedule in 1978 revoked the DTC incentive arrangement. After that date, the government had no way to enforce DTC. The reporting structure was maintained throughout FSD deliveries and eventually discontinued without a formal conclusion.

The following observations can be made about the F/A-18 experience:

- The contractor saw the Navy as being unwilling to trade other system parameters, e.g., performance for cost.
- Design, performance, and cost interrelationships were not established during the program conception phase to allow cost-reducing design tradeoffs.
- The original DTC goal was not continually updated and tracked through changes in design, performance, production quantity, and schedule.
- Parametric cost estimates often vary widely from actual costs, yet parametric cost estimates were not updated to reflect actual costs as the data became available. This practice would permit an accurate and timely assessment of DTC program effectiveness.
- The contractor saw the Navy as placing insufficient emphasis on DTC.
- The Navy saw the contractor as appearing to make a sincere effort to implement the DTC program, but failing to follow it through.

Appendix E presents more details on the F/A-18 program.

2. A-10 Aircraft

In December 1970, development contracts for A-9 and A-10 prototypes were awarded respectively to Northrop Corporation and Fairchild Republic Division, Fairchild Industries. The firm-fixed-price contracts, void of the usual military specifications, standards, and other normal procurement requirements, provided the contractors with maximum flexibility to trade performance and cost. The most noteworthy example of this flexibility was that the selection of the engines for the prototype was left entirely to the airframe contractor and the engines would not be government-furnished equipment (GFE) until the winning airframe was selected. In March 1973, following the competitive Air Force flight evaluation of the full scale development and production proposals, contracts were awarded to Fairchild Republic and General Electric as the airframe and engine contractors, respectively. Fairchild Republic's contract was a cost-plus-incentive-fee (CPIF) contract to build ten (cut to six by Congress in 1974) pre-production aircraft on a negotiated schedule. The incentive was for cost reduction alone, not for increasing performance.

The A-10 has four primary subsystems. The three contracted for by the A-10 System Program Office (SPO) were:

- Airframe and total system integration with Fairchild Republic Division, Fairchild Industries (prime contractor).
- TF-34-100 engines with Aircraft Engine Group, General Electric Company.
- GAU-8/A 33mm gun with Armament Department, General Electric Company.

The fourth subsystem, the avionics, was GFE. DTC clauses were included in each of the contracts prepared at the A-10 SPO.

The main DTC clause defined unit production flyaway costs as the sum of all recurring and non-recurring costs (excluding all RDT&E costs) necessary to produce a complete aircraft, including the applicable portion of system engineering and program management. A prime objective during full scale development was to design to a cumulative average unit production flyaway cost of $1.5 million in FY 1970 dollars for a total of 600 aircraft at a maximum rate of 20 aircraft per month.

The DTC objective was the requirement stated in the initial RFP. The competing contractors were provided the latitude to make tradeoff studies to achieve maximum system performance while meeting the DTC objective.

The contractor was held responsible for controlling and tracking its portions of the costs and for reporting any cost changes over $3,000 on the Monthly Cost Performance Report in both current and FY 1970 dollars. Also, any proposed actions or tradeoffs to bring the costs back within the limit had to be reported. The uncertainty of inflation did not affect the cost goal because it was expressed in constant dollars. The costs applicable to the DTC goals were separately collected, recorded, and reported. The Total System Integration Responsibility clause made Fairchild responsible for ensuring that the entire system cost remained within the $1.5 million cost goal. Failure on the part of Fairchild to meet the DTC goal in any of the areas discussed could result in possible contract termination [IX-5].

Noteworthy features of Fairchild's implementation of DTC are:

- The way the company organized the design team
- The emphasis placed on applying more money in the prototype phase to produce a "production similar" prototype aircraft
- The selection of an high-thrust engine already developed, the extensive use of trade studies, and the use of an iteration process with the engine manufacturer to reduce engine costs.

According to Fairchild, the A-10 design tradeoffs and lessons learned during the prototype development allowed for a significant reduction in production costs, which permitted the Air Force to minimize its spare parts inventory. Table IX-1 shows the A-10 schedule and cost outcomes.

Table IX-1. A-10 Schedule and Cost Outcomes Versus All Tactical Aircraft Outcomes

	A-10	All Tactical Aircraft (8)
Development Cost Growth	1.27	1.18
Development Schedule Growth	1.08	1.03
Development Quantity Growth	0.71	1.10
Production Cost Growth	1.34	1.25
Production Schedule Growth	0.98	2.12
Production Quantity Growth	1.00	1.65
Total Program Cost Growth	1.33	1.23

Compared with all tactical aircraft in our study, the A-10 total program cost growth is 10 percentage points higher. This indicates that the A-10 program did not do better than non-DTC programs. However, the A-10 System Program Office paper [IX-6] defended the program's success by stating that the DTC concept should not be used only as a mechanical, numerical tracking system: "We don't know how much it saved, but are convinced, without any reservations, that the A-10 aircraft is a significantly less expensive system today than it would have been without the application of the DTC concept."

The following observations about the A-10's DTC program may have contributed to the program's success:

- Achievable goals were established early in the program conception phase.
- Aircraft requirements were realistically set.
- A prototype was developed.
- Through necessary tradeoffs, acceptable performance was provided within a price the government could afford to pay.
- Contractors, managers, and engineers were kept informed.

3. AH-64 Helicopter

The AH-64 program had DTC tracking from its outset. The program commenced with a design-to-unit-production-cost goal of $1.4 million to $1.6 million in FY 1972 dollars that was later changed to a unit flyaway cost of $1.8 million in FY 1972 dollars. Due to additions to DTC goals to reflect definitive changes in DoD Instruction 5000.33 for flyaway costs--the impact of changes in mission equipment to include the Hellfire missile and the Target Acquisition Designation Sight/Pilot Night Vision Sensor (TADS/PNVS) subsystems, adoption of the Armament Development Enfield/Direction D'Etudes et Fabrication D'Armament (ADEN/DEFA) 30mm rounds area weapon subsystem, and changes in GFE-- the DTC goal grew to $3.05 million in FY 1972 dollars by FY 1987 [IX-7].

Table IX-2 presents our analysis of the AH-64 program cost and schedule outcomes versus all helicopter programs in our database. As presented, the AH-64 total program cost growth is 20 percent higher than all helicopter programs in our study.

Among the findings from the AH-64A acquisition management practices are the following:

- DTC did not serve to discipline cost growth, especially for non-recurring tooling, engineering, and program management service costs.
- DTC was not fully executed. DoD did not have enough manpower to conduct the in-depth analysis required.

Table IX-2. AH-64 Schedule and Cost Outcomes Versus All Helicopter Outcomes

	AH-64	Helicopters (5)
Development Cost Growth	1.26	1.36
Development Schedule Growth	1.49	1.16
Development Quantity Growth	1.00	0.93
Production Cost Growth	1.74	1.46
Production Schedule Growth	0.83	1.01
Production Quantity Growth	1.26	0.95
Total Program Cost Growth	1.59	1.39

Two lessons can be learned from the AH-64A DTC application:

- A DTC program may not serve to discipline cost growth.
- A prototype during engineering development (or advanced development) is necessary.

Appendix E presents further information on the AH-64 program.

E. ANALYSIS

Of the 89 programs in our study, 32 programs, or 36 percent, have DTC application. Table IX-3 presents a comparison of the average total cost growth between the DTC programs and the non-DTC programs for the programs for which we had complete program data. Figure IX-2 illustrates this comparison.

As shown, the overall cost growth in DTC programs is 19 percentage points greater than that of the non-DTC programs. Overall statistics of the 89-program sample in our study indicate that the DTC concept has not been effective as presently practiced.

However, the analysis of cost and schedule outcomes of DTC versus non-DTC programs by time period indicates that DTC programs were successful in the late 1970s. In that period the cost growth of the DTC programs is only 48 percent and that of the non-DTC programs is 83 percent [IX-8]. It may be that, by the late 1970s, the DTC concept had had enough time to become established and to be applied early enough in a program to be effective. A summary of cost and schedule growth by time period is presented in Table IX-4, and illustrated in Figure IX-3.

Table IX-3. Summary of Cost and Schedule Outcomes of DTC Versus Non-DTC Programs

	DTC	Number of Programs	Non-DTC	Number of Programs
Development Cost Growth	1.32	32	1.25	48
Development Schedule Growth	1.43	32	1.28	49
Development Quantity Growth	1.05	32	1.17	44
Production Cost Growth	1.78	27	1.57	36
Production Schedule Growth	1.67	27	1.64	30
Production Quantity Growth	1.20	27	1.24	36
Total Program Cost Growth	1.63	27	1.44	36

Note: Figures are dollar-weighted.

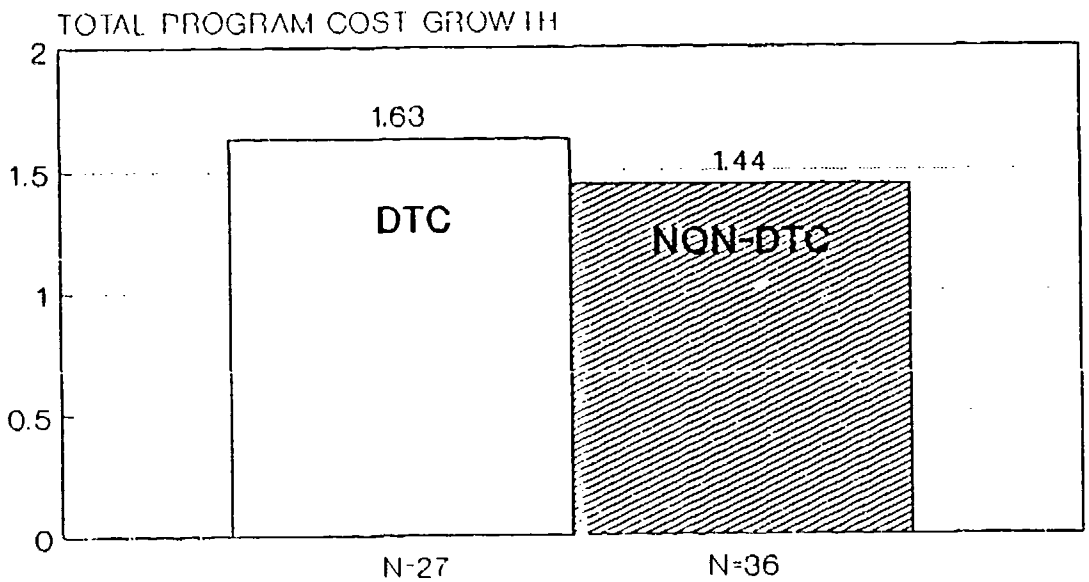


Figure IX-2. Average Total Program Cost Growth of DTC Versus Non-DTC Programs

Table IX-4. Summary of Cost and Schedule Outcomes of DTC Versus Non-DTC Programs by Time Period

Time Period	No. of Programs	DCG	DSG	DQG	No. of Programs	PCG	PSG	PQG	TPCG
Late 1960s									
DTC	1	1.72	3.00	1.19	1	6.61	1.12	0.02	5.19
Non-DTC	21	1.36	1.38	1.17 (19)	20	1.64	1.67 (17)	1.05	1.50
All	22	1.36	1.46	1.17 (20)	21	1.89	1.64 (18)	1.00	1.66
Early 1970s									
DTC	5	1.40	1.42	1.42	5	1.60	1.76	0.92	1.53
Non-DTC	7	1.20	1.11	1.26	6	1.18	1.94 (4)	1.34	1.18
All	12	1.25	1.24	1.33	11	1.42	1.84 (9)	1.15	1.37
Late 1970s									
DTC	21	1.29	1.40	0.96	19	1.55	1.73	1.40	1.48
Non-DTC	9	1.26	1.30	1.14	7	2.17	1.59	1.78	1.83
All	30	1.28	1.37	1.01	26	1.73	1.69	1.50	1.59
Early 1980s									
DTC	5	1.25	1.26	1.03	2	0.92	1.15	0.58	0.93
Non-DTC	11	1.13	1.19 (12)	1.13 (9)	3	0.91	1.00 (2)	1.02	0.91
All	16	1.16	1.21 (17)	1.09 (14)	5	0.91	1.07 (4)	0.85	0.92

Note: Figures are dollar-weighted.

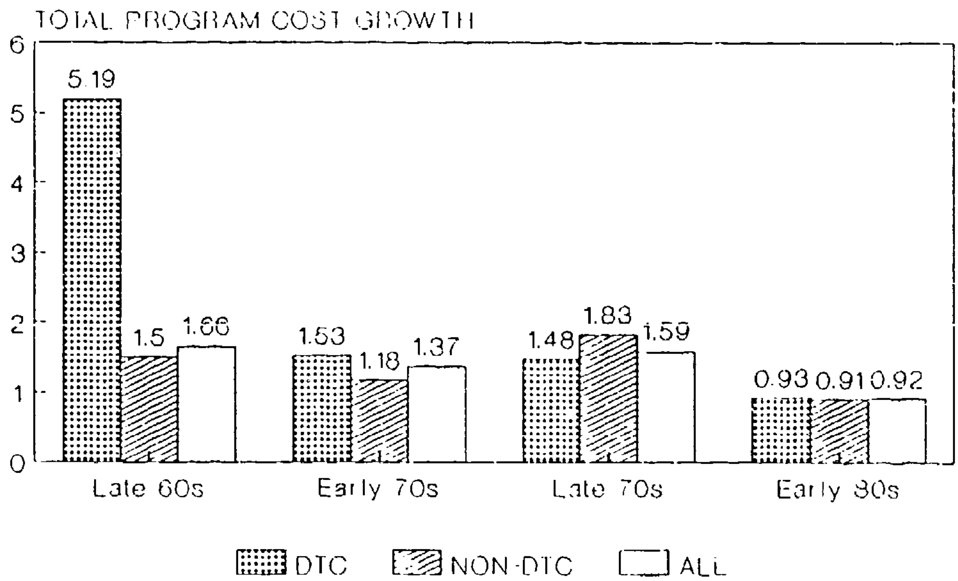


Figure IX-3. Total Program Cost Growth of DTC Versus Non-DTC Programs by Time Period

A case-by-case analysis indicates that the typical method of implementing DTC on the acquisition of major weapon systems have substantially reduced its potential effectiveness. The primary reasons for this are:

- Most systems we had information on had the DTC requirements forced upon them as a retrofit, after initial R&D contracts were awarded. Because of this retrofitting, it is difficult to evaluate the effectiveness of DTC.
- System performance is still the first priority. Traditional emphasis on performance and schedule resulted in a relatively low priority being given to cost.
- DTC has been used mainly as a cost-monitoring device in FSD rather than as a tool for making tradeoffs earlier in the process.
- Use of data and feedback on DTC has not been sufficient to encourage contractor emphasis on DTC programs.
- There has been an absence of continued technical evaluation of design/effectiveness/cost tradeoffs throughout the program acquisition phase.
- There has been no standardized method to implement DTC. Each DTC program uses its own management approach and definition. For example:
  - The A-10 program introduced a 10-year life-cycle-cost requirement, but the emphasis was on meeting the stringent unit production cost goal for continued support.
  - The Utility Tactical Transport Aircraft System (UTTAS) program placed contractual DTC goals and incentives on average airframe production cost.
  - The contractor's cost model for the CH-47 modification program did not include the impact of tradeoffs in achieving DTC unit production goals on operation and support costs.
  - The F/A-18's DTC value was based on a cumulative average recurring cost for 800 aircraft.
  - The AH-64A's DTC cost goal was based on the production cost for the A-10 airframe.

Generally, DTC targets (affordability limits) were not established during concept formulation, when the greatest flexibility existed to maximize total performance for the dollars available (AMST, UTTAS, and CH-47 modification) [IX-9].

DTC has the potential to produce significant cost reductions beyond those achieved if problems experienced could be resolved. However, most DTC programs have been given lip service only.

F. FINDINGS AND RECOMMENDATIONS

DTC has not been effective as practiced. Most DTC programs applied DTC either as a retrofit or too late in the development phase (full scale development) to be cost-effective. As our macro-analysis of the database indicates, cost growth is greater for DTC programs than for non-DTC programs, except in the late 1970s. This exception may be because the DTC concept had become well enough established by the late 1970s to be implemented earlier in the programs.

However, DTC can work if applied properly. To be cost-effective, DTC should be implemented early in the conception phase where design tradeoffs are still feasible. It is important that the DTC goal be established as early as possible in the development cycle, because it is the early design decisions, that will have the most effect on cost.

REFERENCES

[IX-1] Beeckler, Eugene C., and Charles A. Correia. *Award Fee Influence on DTUPC*. U.S. Army Procurement Research Office, Fort Lee, VA.

[IX-2] Defense Systems Management College. *Acquisition Strategy Guide*. Fort Belvoir, VA, July 1984.

[IX-3] Busek, Joseph R., Jr. "A Historical Analysis of Total-Package Procurement, Life Cycle Costing, and Design-to-Cost." Thesis, School of Engineering,of the Air Force Institute of Technology, June 1976.

[IX-4] "Implementation of Design-to-Cost Concept From the Contractual Point of View." *Defense Management Journal* (September 1974).

[IX-5] Tizio, Vincent. "A-10 Design-to-Cost." *The Implementation of Design-to-Cost*. Design-to-Cost Council Seminar, Palo Alto, CA, 1974.

[IX-6] Adams, C. W., and U. A. Hinders. "Design-to-Cost for the A-10 Close Air Support Aircraft." AIIA Paper, No. 74-963, Aeronautical Systems Division, Wright-Patterson Air Force Base, OH, August 1974.

[IX-7] Defense Systems Management College, Department of Research and Information. "Lessons Learned: Advanced Attack Helicopter." Fort Belvoir, VA, July 1983.

[IX-8] F/A-18 Selected Acquisition Reports, March 1976, December 1976 and December 1987.

[IX-9] Report to Congress by the Comptroller General. *Application of Design-to-Cost Concept to Major Weapon System Acquisitions*. PSAD-79-24, 23 April 1979.

X. TOTAL PACKAGE PROCUREMENT AND FIXED-PRICE DEVELOPMENT

We analyzed total-package procurement (TPP) and fixed-price development (FPD) together because they seem related. Both TPP and FPD shift risk from government to contractor. There is a lot of historical evidence on the TPP concept, but there is not enough evidence on FPD to make a final determination as to its effectiveness.

Total package procurement involves considerable risk for the contractor in both development and production, while fixed-price development involves risk in development, but not in production. Total-package procurement was begun in the 1960s, and fixed-price development was begun in the 1980s.

A. TOTAL PACKAGE PROCUREMENT

Total package procurement (TPP) was one of the first major initiatives developed by the Department of Defense (DoD) as an effort to restrain cost overruns in the weapon systems acquisitions process.

1. Background

In the mid-1960s, successful development contracts were generally followed by production contracts. Little or no likelihood existed that the developer would have to face competition. Thus, the contractors had incentives to "buy in"--to underestimate the cost of development programs in order to win the development contract and place themselves in a sole-source position for the much larger follow-on production contracts.

To attack this problem, Robert H. Charles, the Assistant Secretary of the Air Force at the time, designed the total package procurement concept. The objectives of this concept were:

- Limit or eliminate buy-in considerations.
- Motivate contractors to design for economical production and enforce design discipline.

- Encourage subcontracts with, and obtain components from, the most efficient supply sources.
- Obtain long-term commitments leading to program stability and continuity.
- Encourage contractor efficiency through competition and thereby reduce costs.

According to Charles, TPP would allow the government, like any buyer in the commercial world, "to make a choice between competing products on the basis, not of estimates, but of binding commitments concerning performance and price of operational equipment" [X-1].

TPP required contractors to bid on the development, production, and spare-part support work under one contract. Price and performance commitments were obtained during the contract definition phase. The purpose of the TPP contract, generally of a fixed-price incentive type, was to offer the government the opportunity to shift the major risk and major program management responsibility to contractors.

The TPP concept fell far short of its goal. Cost overruns continued, new defense systems failed to meet technical performance requirements, and schedules slipped on many programs. The reasons for the failure of the TPP concept are many. The onset of inflationary pressures in the economy during the Vietnam era--unrelated to a specific program--may have been partially responsible for the failure of the TPP concept. More importantly, TPP did not provide contractors with sufficient management flexibility to cope with problems as they became known. Contractors had to make substantial production commitments to meet delivery schedules before completion of design and verification by testing. Costly redesign and rework followed. Continued tradeoff analysis was stifled because of the rigidity of the contracts.

Although the Air Force Maverick air-to-surface missile program successfully used the TPP concept, serious problems were encountered on many other total package procurement programs. Among those troubled programs were the Air Force Galaxy C-5A transport and Short-Range Attack Missile (SRAM); the Army Cheyenne AH-56A; helicopter, which was canceled, and the Navy DD-963 destroyer. As a result of the problems encountered, DoD recognized the need to place stringent limitations on the application of TPP. By 1972, TPP was abolished by the Deputy Secretary of Defense.

2. Benefits and Weaknesses

The expected benefits of the TPP concept at the time of its introduction included:

- Better definition of design specifications. The TPP concept requires design tightening and configuration discipline on the part of the contractor. At the same time, it forces the government to define, early in the program, specifically what it wants.
- Less unrealistic "salesmanship" or "buy-in" bidding. TPP was designed to allow the Department of Defense to make a choice among competing contractors on the basis of binding commitments on the performance and price of the system.
- Better contractor commitment to design for economical production, reliability, and maintainability.
- More efficient selection of vendors. The contractor is motivated to obtain supplies from the most efficient sources.
- Less need for subsequent competitive reprocurement of components. This is due to increased competition at program initiation.
- More efficient contractors. The winning contractor is more efficient due to tougher competition at the beginning of the program.
- Better long-range planning required by both the government and the contractor.

Despite these promises, the TPP concept has some weaknesses. By attempting to fix a price on a paper concept for a future system, TPP fails to recognize risks involved in taking a design from paper to reality--potential for cost growth and technological risks. The costs identified by the contractor are only estimates and should be treated that way--provisions should be made for periodic updating. Also, the specific definitions of performance requirements, schedules, and production quantities restrict the contractor's ability to perform in the most cost-effective way when moving from design to actual hardware [X-2].

3. Typical Application

Total package procurement contracts were implemented on a number of major defense programs, including the multibillion dollar C-5A transport aircraft. All TPP contracts have been fixed-price incentive. Although reservations about the use of TPP on a large program such as the C-5A were voiced, the government typically did not enforce the contract in the event that the other side failed to perform. The C-5A contract had a repricing clause that permitted Lockheed to make up its losses on the initial contract if an order were placed for subsequent purchases of the C-5A aircraft. As a result of the serious cost problems encountered with the C-5A and several other total package programs, the Air Force chose to convert the C-5A contract to a cost-reimbursement contract [X-1]. The contractor was required to sustain a substantial, but not total, loss on the program. A similar decision was made when difficulties occurred on the Lockheed contract for the development of the Army's AH-56A Cheyenne helicopter.

Typical of TPP contracts was the government's inability to enforce the contract if the contractor failed to perform. When problems occurred, the fixed-price contracts were converted to cost-reimbursement type contracts, and the contractors were required to take substantial losses on the programs.

4. Cases Examined

The specific TPP cases examined were the C-5A aircraft, the SRAM, and the Maverick AGM-65A missile.

a. C-5A Aircraft

The C-5A was the first major program procured under the TPP concept. The C-5A airframe contract (issued on 1 October 1965 to Lockheed) called for 5 test and 53 production aircraft and included options for an additional 142 aircraft under two follow-on provisions. It was a fixed-price contract that held the contractor accountable for expected levels of aircraft performance as well as for price and production schedule compliance.

The major problems attributable to the TPP process as it affected the C-5A acquisition were lack of contract flexibility and concurrency. The Air Force contract managers held fast to specified performance standards and program schedule milestones, and allowed little or no negotiation when the contractor experienced design problems. The result of this inflexibility was that Lockheed made design and managerial decisions that ultimately degraded the performance of the aircraft. The urgency placed on the development and acquisition of the C-5A led to the concurrency problem--initiation of production prior to the solution of design and development inadequacies. The procurement process was further aggravated by the effects of high inflation in the economy in general. The stringent requirements on meeting specified price and performance standards increased cost growth substantially. Thus, the downfall of the TPP was precisely what it was designed to prevent--uncontrolled cost [X-2].

See Appendix F for further information on the C-5A program.

b. Short-Range Attack Missile (SRAM)

The SRAM was the second weapon system procured under the total package procurement concept. It is an air-to-surface missile designed to maintain high confidence of successfully attacking targets defended by sophisticated defense systems. The SRAM was planned to be carried on B-52G/H, and FB-111 aircraft. The development and production contract was awarded to the Boeing Company on 21 November 1966. Experience with the SRAM has shown that TPP was not successful for several reasons:

- Definition. In the time allowed, the system TPP was not adequately defined.
- Cost estimation. Production costs could not be realistically forecast before development testing.
- Technology. Some hardware requirements turned out be beyond the state of the art.
- Concurrency. Concurrent development of SRAM, the FB-111, and the Mark II avionics caused major interface changes.
- Disengagement concept. The concept of disengagement whereby the contractor would be solely responsible for the performance of the contract and the government would monitor the progress of the program and determine when they should "engage" proved to be costly in terms of timely resolution of problems. This cost both parties time and money.
- Interface management. The total SRAM program involved a considerable number of industry and government participants. There was, however, no authority for joint problem resolution or assuring that all participants had the same objectives and were working to a common plan. Channels for problem resolution were uncertain and time-consuming.
- Contract baseline changes. During the proposal period, several changes were made to interfacing contractor requirements, some of which were accepted without contract change authorization or incorporation into the baseline contract. A number of SRAM system design changes were necessary to the FB-111/SRAM Carrier Aircraft Equipment (CAE), the missile, and as a result, to the B-52/SRAM CAE. These changes had a detrimental effect on the cost of the SRAM DT&E program and on the eventual cost of production. These costs were not included in the fixed-price incentive contract for both DT&E and the production options [X-3].

c. Maverick AGM-65A Missile

The Maverick AGM-65A was a successful program procured under a TPP contract. It was initiated when many, if not all, TPP programs were encountering major problems. The prime contractor was Hughes Aircraft Corporation. The TPP contract was fixed price with cost, schedule, and performance incentives of 50/50 under target, 70/30 over, and up to 125 percent of target cost. That is, the contract had a price ceiling of 125 percent of target cost, and the incentive (usually a percentage of target cost) was cost sharing between the government and the contractor of 50/50 if the program was under target, and 70/30 if the program was over target.

Two important contractual features led to the success of the program: (1) two-way incentives with awards for good performance and penalties for unacceptable performance and (2) an escalation clause. A number of lessons can be learned from the success of the Maverick program. They are:

- Program continuity provides major payoffs
- Modest expenditures at the beginning of a program to define and investigate potential programs will prevent later schedule slippage and major cost growth.
- Selection of known technology that is appropriate to the real need in lieu of high-risk technology is a key to predictable performance, schedule, and cost.
- The selection of efficient options for production rates yields large unit cost savings.

See Appendix F for more information about the Maverick program.

5. Analysis

Our analysis shows that the total cost growth in TPP programs is greater than the cost growth in non-TPP programs by 42 percentage points. The outcomes of TPP programs and the outcomes of the TPP versus non-TPP programs are presented in Table X-1 and Table X-2, respectively.

Table X-1. Cost and Schedule Outcomes for TPP Programs

Systems	PCG	PSG	PQG	TPCG
C-5A	2.15	1.19	0.66	1.77
SRAM	5.53	1.25	2.14	3.39
Maverick AGM-65A	0.84	–	1.18	0.95
Average cost growth	2.32	1.22	1.33	1.91

Table X-2. Cost and Schedule Outcomes of TPP Versus Non-TPP Programs

	TPP	Number of Programs	Non-TPP	Number of Programs
Production Cost Growth	2.32	3	1.61	60
Production Schedule Growth	1.22	2	1.67	55
Production Quantity Growth	1.33	3	1.22	60
Total Program Cost Growth	1.91	3	1.49	60

Note: Cost growth figures are dollar-weighted.

While the goal of the TPP concept was desirable, the quantum leap in acquisition practice that implementation of the concept represented was a factor in its failure. TPP was an effort to change 30 years of acquisition in a single step. It depended on details and projections never before attempted for large programs. For example:

- It required detailed specification of performance requirements, schedules, and production quantities before a single piece of hardware had been built.
- It required that the contractors project requirements far into the future and provided no provision for revision.
- It attempted to set a firm price on the development and production of a complex system before any part of that system had been constructed.

The total package procurement concept shifts the major role of government personnel from the acquisition phase to the conceptual and definition phases. TPP shifts risk from the government to the contractor. To a certain extent, risk shifting may be a good idea. In private industry, companies that develop products bear all the risk. If those products are not acceptable to consumers, the firms are unable to sell them, and they lose money. Ultimately, these firms may fail. However, in major weapons systems, the product is developed on a customized basis for the government. If the government shifts too much risk onto the contractor and there is an overrun, the contractor's existence may be jeopardized. Then, the government has to decide whether to let the contractor go out of business or bail it out. In the case of the C-5A, the government decided to bail out Lockheed. Further, if contractors know that they are going to be bailed out, then major risk-shifting becomes less effective.

The experiences with the C-5A, the AH-56A helicopter, and the SRAM confirm that TPP emphasized the importance to the government of a good request for proposals (RFP), since the production program had to be defined in sufficient depth to permit the contractor to submit a firm proposal. Unless the contractor is given a clear indication of the value of various levels of system performance, the contractor will very likely attempt to provide a minimum cost system consistent with the specifications associated with the work statement in the contract [X-4].

The total package procurement concept might have been successful if it had been implemented in a more orderly fashion, and if adequate time had been provided for both the government and the contractors to develop an understanding of the implications of the concept--the concept was introduced in mid-1964 and was first applied to a major system a few months later.

6. Findings and Recommendations

For the most part, the total package procurement concept is a failure. It should not be implemented except in rare circumstances. TPP is most likely to have serious adverse effects on innovation and quality in systems developments where the requirement is uncertain, the need is extremely urgent, the technology that must be used is unproven, or the measures of systems effectiveness are diffuse and qualitative.

In order to implement TPP, the following conditions should exist:

- The system should be thoroughly and clearly defined in a contract definition phase.
- The program should be a low-risk development.
- The project should be short-term (5 years or less).
- An announcement should be made at the outset of the program that substantial changes are not permitted.

The Maverick AGM-65A proved that TPP can work if the above conditions exist. However, because most of the SAR programs are high-risk, it should generally not be applied In particular, if the government and the contractor cannot agree on a stable system definition, the TPP should not be applied.

B. FIXED-PRICE DEVELOPMENT

Fixed-price development was instituted by the Navy in order to encourage an efficient development process without the major risk of total package procurement.

In a firm-fixed-price contract, the contractor theoretically accepts all risks in exchange for the stated price. The government is required to make nc price adjustment for the original work after the contract is awarded, regardless of the contractor's actual cost in meeting requirements. Exceptions occur in cases of government-approved contract changes made in response to changes in military requirements, technology, and funding. Changes may also be made in cases involving the "Truth in Pricing" law. This law makes provisions in cases where the contractor did not disclose information available at the time of the negotiation, causing inaccurate estimates. The firm-fixed-price contract can be defined as a contract that specifies a certain amount to be paid for the designated system, regardless of the contractor's cost experience.

1. Background

The practice of firm-fixed-price contracting by the Department of Defense (DoD) has gone through many changes over the past twenty years. In 1952 fixed-price contracts represented 82 percent of defense prime contract awards. By 1961 this had dropped to 58 percent. Defense Secretary Robert McNamara raised the percentage to 79 percent in 1966; by 1970 the fixed-price percentage had dropped to 74 percent.

Although the percentage of fixed-price contracts is partly a function of the type of work to be performed, it is heavily influenced by Pentagon policy. It is used to shift the burden of cost control from the DoD to the contractor. After 1969, the Laird-Packard influence led to a decline in fixed-price contracting and an increase in the use of cost-reimbursement contracts for research and development work. The Laird-Packard administration believed that large research and development programs are impeded by rigid fixed-price contracts because they reduce the government's ability to observe what is happening during the life of the contract.

In theory, the DoD selects a contract type that will provide a reasonable distribution of risk between government and industry. Fixed-price contracts provide the greatest risk to contractors, and also award the highest profit rate [X-5].

2. Benefits and Weaknesses

Firm-fixed-price contracts closely resemble commercial contracts. The Defense Procurement Handbook uses the following terms to describe them:

> At a specified price, the contractor assumes all financial risks to performance. His profit depends entirely on his ability to control his costs. The government bears no risk of loss under the contract. A firm-fixed-price contract thus gives the contractor the maximum incentive to avoid waste, to use production and subcontracting methods that will save labor and materials.

The firm-fixed-price contract has another great advantage for the government: it is relatively easy and inexpensive to administer. It also benefits the contractor: the government does not monitor contractor costs, so the contractor does not have to conform accounting methods to DoD audit procedures. Administrative costs are therefore lowered.

For the contractor, the expected benefits of the firm-fixed-price contract are as follows:

- Higher profit potential
- Minimum government control
- Minimum government auditing.

On the other hand, the contractor may have to assume all the financial and technical risk and the risk of greater liability for work being performed [X-5]. This is particularly a problem in development, when the design is not yet established.

3. Typical Application

Realistically, two important conditions should exist before a firm-fixed-price contract is negotiated:

- Reasonably definite design or performance specifications must be available.
- The contracting parties must be able to establish at the outset prices that are judged to be fair and reasonable.

In formally advertised procurements, the existence of definite specifications and adequate competition satisfies these conditions. Even when price competition is not present, a firm-fixed-price contract may be appropriate if one of the following conditions exists:

- Historical price comparisons can be made
- Available cost or pricing data permit realistic estimates of probable performance costs
- Contract performance uncertainties can be so clearly identified that their impact on price can be evaluated.

When none of these conditions exists, the use of a fixed-price contract with an incentive feature, or a cost-reimbursement type of contract, is normally considered more appropriate. Fixed-price contracts are often used for late production lots, when the system and production methods are well-defined.

Most recently, in the 1980s, Navy Secretary John Lehman advocated fixed-price development as a means of saving the government money and shifting risk from the government to the contractor. In development, fixed-price contracts involve greater risk for the contractor.

Fixed-price development contracts were used for many research and development programs, including the F-111 aircraft, AH-56A Cheyenne helicopter, F-14A aircraft, and the new high-tech V-22 Osprey aircraft. These are long-term, high-risk programs. Generally, when the contractor failed to perform (e.g., the Cheyenne helicopter and the F-14A), the firm-fixed-price contracts were changed to cost-reimbursement type contracts.

4. Cases Examined

Two cases of FFP contract application are examined here: the V-22 and the F-14A aircraft.

a. V-22 Aircraft

The V-22 program is one of the "highest tech" of all aviation acquisition programs. It calls for 6 RDT&E and 913 production aircraft. A fixed-price FSD contract was awarded to Bell Helicopter Textron and Boeing Vertol, as joint contractors, on 1 May 1986. Presently in its FSD phase, the V-22 program is experiencing some potential engineering problems that could degrade its operational effectiveness. The acquisition strategy and new technologies contained in the V-22 program could involve risks that are too high for the government, the contractor, or both. With the application of a firm-fixed-price development contract, the operational engineering problems and safety of the V-22 could be degraded by engineering problems, which in turn could lead to cost increases and schedule delays.

Appendix F contains additional details about the V-22 program.

b. F-14A Aircraft

The information on the F-14A acquisition was derived from interviews with individuals in the defense industry, contractor offices, and government program offices. The F-14A started out as a TPP program and evolved into a fixed-price development program.

The Grumman Aerospace Corporation entered into a long-term, fixed-price contract with the Navy for the development and production of varying quantities (lots) of F-14A aircraft from early 1969 through 1977. The contract provided that Grumman would design, develop, and furnish six model F-14A aircraft (lot I) and granted the government the option to purchase seven additional lots of aircraft, one in each fiscal year through 1976. The contract provided that the price of lot II and subsequent lots of aircraft would be determined by negotiations between the parties, but would not exceed the ceiling prices specified therein. (Each lot has a stated quantity of aircraft called the "nominal quantity," and the government may order any number of aircraft from 50 percent below to 50 percent above the nominal quantity.)

The price to be paid by the government for each lot of aircraft was to be determined by negotiation between the parties based on the estimated cost of actually producing that lot. But the negotiated price could not exceed the ceiling prices set forth in the contract. The ceiling prices were not subject to negotiation or change except as they are affected by the "contract" provisions, change orders, and in the case of lot VI and subsequent lots, the escalation clause. The escalation clause would be applicable to lots VI, VII, and VIII only. Grumman performed lot I through III under the terms of the contract, but anticipated cost overruns for lots IV through VIII.

Due to extraordinary economic conditions since early 1969 and to the fixed-price contract, Grumman projected financial losses so enormous that the continued existence of the company was threatened. In March 1971, Grumman informed the Navy that production of lots IV through VIII of the contract would be commercially impracticable under the existing terms and conditions. Just for lot IV, Grumman projected a loss $95.3 million. According to Grumman, factors contributing to the F-14A cost increase were high inflation and a sharp increase in the overhead attributable to this contract due to a drastic reduction in the level of Grumman's defense and aerospace business base [X-6].

Because of the nature of the contract, Grumman was discharged from its obligations to perform the remainder of the contract under the initial terms and conditions for the following reasons:

- The causes of the projected loss were abnormal economic conditions.
- The increased cost of performance was highly disproportionate to the contract price.

Table X-3 presents the F-14A cost and schedule outcomes.

Table X-3. F-14 Cost and Schedule Outcomes Versus All Tactical Aircraft

	F-14A	Tactical Aircraft (8)
Development Cost Growth	1.44	1.18
Development Schedule Growth	1.16	1.03
Development Quantity Growth	2.00	1.10
Production Cost Growth	1.25	1.25
Production Schedule Growth	3.18	2.12
Production Quantity Growth	1.26	1.65
Total Program Cost Growth	1.28	1.23
Stretch	2.52	-

In comparison to all tactical aircraft, development cost growth of the F-14A is 26 percentage points higher. Note that production cost growth is the same, probably due to the contract change from firm-fixed-price to cost plus incentive fees. Total program cost growth is only 5 percentage points higher than all tactical aircraft. Statistically, the F-14A program outcomes are good--this may be an indication that fixed-price development (FPD) gave the contractor the incentive to hold costs down.

4. Analysis

Because there is relatively little production experience in these firm-fixed-price development programs, our conclusions are tentative. Our analysis of 7 fixed-price versus 73 non-fixed-price programs indicates that the development cost growth of the firm-fixed-price development programs is 28 percentage points higher than that of the non-fixed price. There is not enough production data to evaluate the total program cost growth.

The development cost and schedule outcomes are presented in Table X-4.

Table X-4. Cost and Schedule Outcomes of FPD Versus Non-FPD Programs

	FPD	Number of Programs	Non-FPD	Number of Programs
Development Cost Growth	1.52	7	1.24	73
Development Schedule Growth	1.27	7	1.35	74
Development Quantity Growth	1.34	6	1.10	70

According to our study (Section IV), higher development cost growth tends to lead to higher production cost growth. It is likely that the FPD programs will have higher cost growth than the non-FPD.

Fixed-price contracts do not solve the problems of cost growth and schedule slippage. Although a long-term fixed-price contract can cut acquisition costs during production, a firm-fixed-price contract from full scale development through production for procuring several hundred weapon systems over several years (e.g., 9 years for the V-22 Osprey, 8 years for the F-14A) is not appropriate.

Most firm-fixed-price contracts examined were written for programs in which the element of uncertainty was too high (the C-5A and V-22, for example). When a contractor fails to perform, the government often amends the contract and allows an increase in price (F-14A). In some cases, a contractor who fails to perform may be required to accept some loss along with the contract change. For example, contract changes forced contractors to absorb losses on the C-5A program, the F-111 program, the SRAM program, and the AH-56A program.

Based on our interviews with the government, it appears that FPD contracts are seldom executed as planned and have to be reopened. The government has difficulty with this, because there is no planned budget to address the problems. If there are problems in development, the cost would roll into production. For example, the V-22 Osprey is exceeding the "not-to-exceed" quota. FPD is likely to force contractors to trade off capabilities to meet target cost.

5. Findings and Recommendations

In short, firm-fixed-price contracts have not been used effectively in development programs. They have not been successful in high-value, high-cost, high-risk, long-term programs.

We recommend that fixed-price development be applied only to programs that meet the following conditions:

- The program is low-cost, low-risk, short-term.
- Historical price comparison can be made.
- Available cost or pricing data permit realistic estimates of probable performance costs.

- Program contract performance uncertainties can be so clearly identified that their impact on price can be evaluated.

Since most of the SAR programs are high risk, it is not appropriate to use FPD in these programs. There is no evidence that FPD contributes to total program cost growth, but there is evidence that it is related to higher development cost growth.

REFERENCES

[X-1] Fox, Ronald J. *Arming America, How the U.S. Buys Weapons.* Harvard University, Graduate School of Business Administration, Division of Research, Boston, MA, 1974.

[X-2] Poncar, Jerry V. and James R. Johnston, II. *History and Analysis of the C-5A Programs: An Application of the Total Package Procurement Concept.* October 1970.

[X-3] Comptroller General's Report to the Vice Chairman, Subcommittee on International Trade, Fiance and Security Economics, Joint Economic Committee. *C-5A Wing Modification: A Case Study Illustrating Problem in the Defense Weapons Acquisition Process.* 22 March 1982.

[X-4] *Lessons Learned on the SRAM Program.* The Boeing Company, March 1974.

[X-5] Glennan, Thomas K., Jr. *Innovation and Product Quality Under the Total Package Procurement Concept.* The Rand Corporation, Memorandum RM-50997-PR, September 1966.

[X-6] Fox, J. Ronald. *Arming America, How the U.S. Buys Weapons.* Cambridge, MA: Harvard University Press, 1974.

XI. CONTRACT INCENTIVES

A. BACKGROUND

Incentive contracting has a long history in acquisition. The early 1960s was an "incentive era" in which the government attempted to reduce costs through increased use of firm-fixed-price and incentive-type contracts [XI-1]. Two general types of incentive contracts are in use today--cost plus (or fixed-price) incentive fee and cost plus (or fixed price) award fee.

In fixed-price-incentive contracts, the contract has a target and a ceiling price. If the contractor meets the target price, it receives the full incentive fee. If it goes over the target price, costs are split with the government according to a sharing formula (50/50, 60/40, etc.) up to the ceiling price. Costs above the ceiling price are covered by the contractor. Incentive contracts can also be written to include incentives for system performance or delivery schedule. However, the most prevalent reason for incentive contracts is to share cost risks with the contractor. The government wants the contractor to produce efficiently and at the lowest cost.

Fixed-price award fee contracts have widely differing structures. Under these contracts, the fee is awarded based upon performance of goals set out in the contract. Award fee contracts are relatively more flexible than incentive contracts. They can incorporate a variety of goals, including non-cost goals such as delivery dates or reliability and maintainability goals. Weights may be given to individual goals. A review board may be appointed to determine how much of the fee is to be awarded.

B. BENEFITS AND WEAKNESSES

Benefits of contract incentives to the government include:

- Cost savings compared with what costs would be in fixed-fee contracts
- The degree to which the contractors behave in the way the government wants.

Advocates of incentive contracts would say that they are a good substitute for competition, which is very difficult to establish in major weapons systems because of the small size of the industry. Incentive contracts are an attempt to create market-like signals in an industry in which competition is difficuit.

Weaknesses of incentive contracts are the additional costs to the government, including the following:

- The extra costs of incentive and award fees over and above those that would be given on cost-plus contracts
- The extra cost of administering these contracts, as opposed to cost-plus contracts. These pertain particularly to award fee contracts.

Evaluating whether such contracts save the government money is difficult because we cannot test the cost of traditional non-incentive contracts under identical conditions.

C. TYPICAL APPLICATION

Incentive contracts are often used in development. In production, they are typically used early on; fixed-price contracts are more popular later.

D. CASES EXAMINED

Our database included 59 programs with incentives of some sort in development and 52 with incentives in production. In most cases, the information we had was an indication of whether or not incentives were used rather than information on types, sharing ratios, and provisions of individual contracts. We did not collect information on the form of incentive contracts used, but we did collect information about contract incentives in the course of performing the case studies for the other initiatives.

One of the programs in our database, the F/A-18 was unique in that the incentive contract was used as an "enforcer" of the design-to-cost provision. Eventually, the design-to-cost goal faded away. The incentive clause in the FSD contract was not completely used, because it hinged on a delivery schedule that was later changed. However, some sort of partial incentive fee award was made. The effect of having the incentive clause is not clear. Our informal observation is that design-to-cost was taken somewhat more seriously on the F/A-18 than on other programs, where it was given mere lip service, and the incentive clause may have been partially responsible.

The General Accounting Office [XI-2] reviewed 62 fixed-price incentive contracts from 1977-84 to determine how the final price of each compared with the contract's established target and ceiling prices. Fifty-six of these contracts were for over $1 million and 22 were for over $10 million each. The GAO expected to find a clustering of final prices very close to the target price and an increasing tendency for final prices to underrun the target price (or for lower overruns) as contractor sharing ratios increased. The GAO found that the final prices on 58 percent of the contracts were within 5 percent of the target, and 92 percent were within 10 percent of the target. However, GAO's findings and other research findings cited in the report were that final contract costs and price seem unrelated to the sharing ratio.

E. ANALYSIS

Figure XI-1 shows a comparison of cost growth for programs with and without incentive contracts from our database. To compare development cost growth, we had information on:

- 27 aircraft, of which 18 had contract incentives
- 34 tactical munitions, of which 26 had contract incentives
- 19 other programs, of which 10 had contract incentives.

To compare total program cost growth, we had information on:

- 25 aircraft, of which 17 had contract incentives
- 27 tactical munitions, of which 20 had contract incentives
- 11 other programs, of which 8 had contract incentives.

The figure indicates that the results are sensitive to the type of equipment studied. In the case of aircraft, cost growth is slightly lower with contract incentives than without. In the case of tactical munitions, cost growth is higher with contract incentives. In the case of other programs--electronics/avionics (development only), strategic missiles, and satellites--cost growth was substantially lower with contract incentives.

F. FINDINGS AND RECOMMENDATIONS

Our findings indicate that for strategic missiles and satellites, contract incentives in FSD and in production are associated with lower total program cost growth. The macro-analysis indicated that incentive contracts in development were associated with lower cost growth in development for strategic missiles and satellites, and the results were statistically significant.

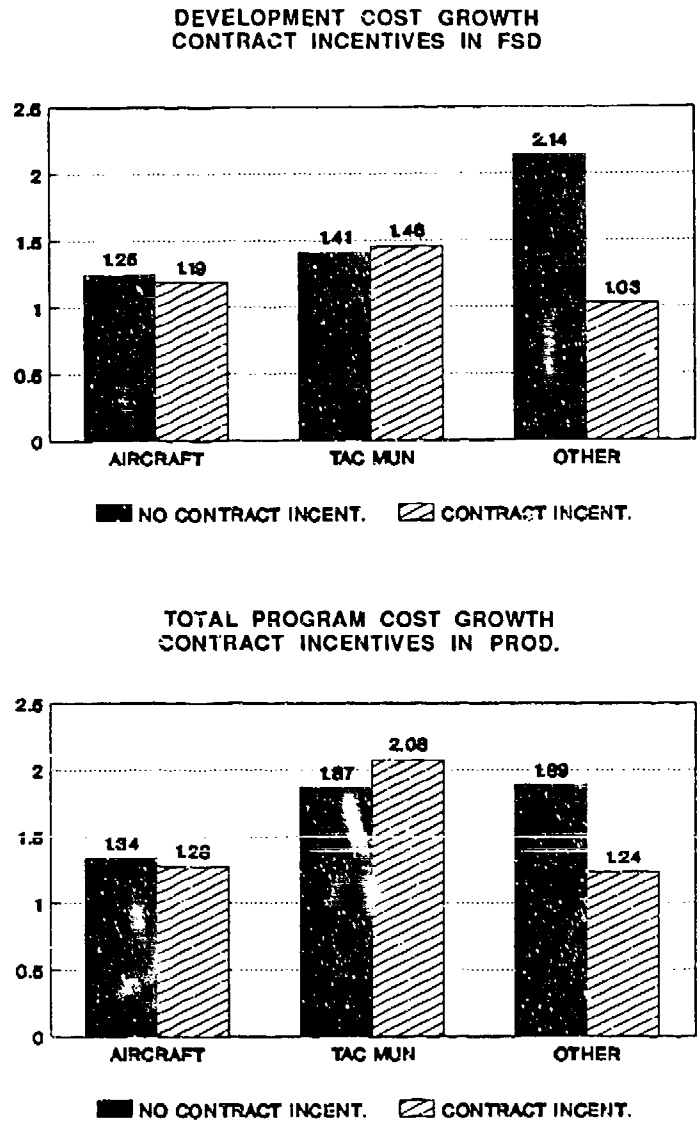


Figure XI-1. A Comparison of Cost Growth for Programs With and Without Incentive Contracts

Our case studies, program office visits, and industry surveys indicated that incentives were successful. Both government and industry believed incentive contracts to be effective, although we did not independently evaluate claimed savings estimates. In general, government representatives believed that they received what they wanted in cases of award fee. Industry representatives pointed out that incentive and award fees, which might seem small as a percentage of the total contract, amount to a large percentage of total allowable profit. Managers' bonuses might be tied to their performance in obtaining full incentive or award fees.

No government representative appeared greatly concerned about the added contract cost of incentive or award fees relative to savings. Only one expressed a concern, and that was regarding the complications of administering award fees.

Our findings on incentive contracts need to be considered in the context of two initiatives with similar cost-reducing objectives--competition and fixed-price development. With respect to competition, incentive contracts appear to be administratively simpler, although the potential savings may be lower. With respect to fixed-price development, incentive contracts appear to be more successful.

Contract incentives as an acquisition initiative is worthy of further study. While we did not do a full-scale analysis of it, our macro and micro analyses pointed to the same conclusion: contract incentives work. In addition, contract incentives are fairly simple and inexpensive to implement.

Based on our analysis, we recommend:

- Wherever possible, incentive contracts should be used in development, and possibly also in early production.
- Incentive contracts should not be used late in production, when the cost of production is generally known.
- Award fees should be considered when customization of goals is desired; however, potential gains from award fee contracts should be balanced against administrative costs.

REFERENCES

[XI-1] Parker, John M. "An Examination of Recent Defense Contract Outcomes in the Incentive Environment." Thesis, Air Force Institute of Technology, September 1971.

[XI-2] U.S. General Accounting Office. "Incentive Contracts: Examination of Fixed-Price Incentive Contracts." GAO/NSIAD-88-36BR, November 1987.

XII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Program cost outcome trends have not been getting uniformly better or worse over time.

   Total program cost growth was high during the late 1960s, lower in the early 1970s, higher in the late 1970s, and lower in the 1980s. We caution that our data on the 1980s are based on a very small set of immature programs; programs tend to accumulate cost growth as they mature.

2. Tactical munitions had the highest total program cost growth.

   Tactical munitions probably have a higher percentage of technological content than other weapons systems. These systems are usually not the highest priority systems in the services and therefore may not receive as much attention from high-level management as needed. Costs for tactical munitions modifications are usually underestimated, because a modification often comprises a new guidance and control system, the largest and the most difficult to estimate part of the equipment cost.

3. As might be expected, modification programs for the most part experience less cost growth than do new starts, except for tactical munitions and electronic aircraft. Experiences with other equipment were generally much better.

4. Development cost growth in avionics was the highest of any equipment type. (We could not evaluate production cost growth for avionics, because these costs are usually contained in platform SARs.)

5. Development cost growth and production cost growth tend to go hand-in-hand. Big problems in development will continue to show up as big problems in production. Development schedule growth and development schedule length are major drivers of total program cost growth.

6. Production stretchout is a major determinant of total program cost growth.

7. Multi-year procurement (MYP) has been successful under the strict guidelines that are used by DoD and Congress to determine candidate programs. Cost growth has been lower in MYP programs than in the general population of programs. This may be in part because these programs had to be fairly stable to pass the guidelines and be accepted. However, cost growth in MYP

programs was less than in a set of rejected MYP candidates, which were also stable.

8. Competition has had mixed success. We have seen examples of both good and bad applications.

9. Prototyping has generally been successful in gaining information to reduce uncertainties for the concept that may go forward into FSD, and equally important, in precluding unattractive options. Evidence indicates that some time and resources are recovered in FSD and that prototyping holds down development and production cost growth.

10. Design-to-cost has not been successful as applied, because it has been applied during FSD, too late in the program to be effective. Design-to-cost has been used as a monitoring device rather than as a design tool. However, by the late 1970s DTC had had time to develop as an initiative, and it appears to have been more successful.

11. Both fixed-price development and total package procurement have been unsuccessful when used for high-value, high-cost, high-risk, long-term programs.

12. Contract incentives in FSD are associated with lower development cost growth. For some equipment types, contract incentives in FSD and in production are associated with lower total program cost growth.

B. RECOMMENDATIONS

1. Provide stable budgets, both at the macro (overall defense budget) and the micro (program) levels.

2. Target tactical munitions and electronics/avionics programs for increased management attention.

3. Develop guidelines for correctly applying initiatives such as competition and prototyping to programs.

4. Continue strict guidelines for selecting programs for MYP. Consider relaxing the guidelines if higher savings are desired and if more risk is acceptable.

5. Be selective in the use of competition. Develop guidelines for competition, including requiring a break-even analysis. Benefits other than cost savings (such as contractor responsiveness, system reliability, and the industrial base) need to be considered.

6. Apply prototyping in advanced development (for systems and critical subsystems) in cases where significant information is to be gained and where the prototype represents only a small percentage of acquisition cost.

7. Use design-to-cost early when design tradeoffs are still feasible (in concept exploration and demonstration/validation), and reward contractors for low-cost production.
8. Do not implement fixed-price development or total package procurement in high-risk, long-term programs.
9. Use a mix of incentive fees and award fees in development and in early production. Use firm-fixed-price contracts in later production.
10. Examine cross-program effects and industry strategies to understand how they affect program outcomes. How industry approaches a program compared with how government does and how changes in a program affect industry strategies and costs are of paramount concern.

Appendix A

VARIABLE DEFINITIONS AND ACQUISITION PROGRAM DATABASE

APPENDIX A
VARIABLE DEFINITIONS AND ACQUISITION PROGRAM DATABASE

PROGID	Program identification number, ranging from 1 to 89
PROGRAM	Program name (condensed)
SERVICE	Service code; 1 for Army, 2 for Navy, 3 for Air Force
EQTYPE	Systems classification; 0 for satellites, 1 for tactical aircraft, 2 for electronic aircraft, 3 for other aircraft, 4 for helicopters, 5 for air-launched tactical munitions, 6 for surface-launched tactical munitions, 7 for electronics/avionics, 8 for strategic missiles
NEW/MOD	Code for new or modification programs; 0 for new programs, 1 for modification programs
TIME	Time period code classified by FSD year; 1 for the late 1960s, 2 for the early 1970s, 3 for the late 1970s, 4 for the early 1980s
FSDST	Year of full scale development start
DEV2	Code for programs that started FSD after 1985; 0 for programs with starts in 1985 or after, 1 for programs with start before 1985 (Only programs with FSD before 1985 were used in the evaluation of development outcomes.)
DCG	Development cost growth
DSG	Development schedule growth
DQG	Development quantity growth
PROD_U	Code for programs that started production in 1985 or before; 0 for programs with production starts in 1985 or after, 1 for programs with production starts before 1985 (Only programs that started production before 1985 were used in the evaluation of production outcomes.)
PCG	Production cost growth

PSG	Production schedule growth
PQG	Production quantity growth
TPCG	Total program cost growth
STRETCH	Measure of program stretchout, PSG/PQG
PRO	Prototype code; 0 for programs with prototype, 1 for programs without prototype
C_PRD	Code for programs that had competition in production; 0 for programs with no competition in production, 1 for programs with competition in production
DTC	Design-to-cost code; 0 without DTC, 1 with DTC
MYP	Multi-year procurement code; 0 without MYP, 1 with MYP
FPD	Fixed-price development code; 0 without FPD, 1 with FPD
TPP	Total package procurement code; 0 without TPP, 1 with TPP
I_FSD	Incentives in full scale development code: 0 without incentives, 1 with incentives
I_PRD	Incentives in production code: 0 without incentives, 1 with incentives

Note: Dots indicate missing data.

ACQUISITION PROGRAM DATABASE

PROGID	PROGRAM	SVC	EQTYPE	MOD	TIME	FSDST	BASEYR	DEV2	DCG	DSG	DQG
1	V-22	2	3	0	4	86	86	0	0.99	1.00	1.00
2	T45TS	2	3	1	4	82	84	1	0.44	1.04	0.50
3	B-1A	3	3	0	2	70	70	1	1.10	1.17	0.80
4	C-5B	3	3	1	4	82	80	1	.	1.00	.
5	C-17A	3	3	0	4	85	81	0	1.20	1.05	1.00
6	C-5A	3	3	0	1	65	65	1	0.98	1.18	1.00
7	B-1B	3	3	1	4	82	81	1	0.96	1.00	.
8	FB-111A	3	3	1	1	66	66	1	2.57	1.42	1.00
9	AV-8A	2	1	0	2	70	70	1	.	.	.
10	F-5E	3	1	1	2	72	71	1	1.05	1.06	1.00
11	F-15	3	1	0	2	70	70	1	1.07	1.03	1.00
12	F-16	3	1	0	3	75	75	1	1.05	0.98	1.00
13	F-14D	2	1	1	4	84	86	1	1.07	1.00	.
14	F-14A	2	1	0	1	69	69	1	1.44	1.16	2.00
15	AV-8B	2	1	1	4	80	79	1	1.11	0.83	1.00
16	A-10	3	1	0	2	73	70	1	1.27	1.08	0.71
17	F/A-18	2	1	0	3	76	75	1	1.15	1.08	1.00
18	E-6A	2	2	0	4	83	82	1	1.12	1.27	1.00
19	E-3A	3	2	0	2	70	70	1	1.37	1.16	3.00
20	EF-111A	3	2	1	3	75	73	1	2.10	1.70	1.00
21	E-2C	2	2	1	2	70	68	1	1.50	0.76	1.00
22	EA-6B	2	2	1	1	68	68	1	1.26	1.00	1.00
23	P-3C	2	2	1	1	65	67	1	1.80	1.00	.
24	LAMPSMK3	2	2	0	3	77	76	1	1.04	1.00	1.00
25	E-4	3	2	0	2	73	74	1	1.88	1.59	1.00
26	S-3A	2	2	0	1	69	68	1	1.09	1.00	0.67
27	CH-47D	1	4	1	3	75	75	1	1.13	1.06	1.00
28	OH-58D	1	4	1	4	81	82	1	0.98	1.20	1.00
29	UH-60A	1	4	0	2	72	71	1	1.08	1.07	0.63
30	AH-64A	1	4	0	3	76	72	1	1.26	1.49	1.00
31	CHEYENNE	1	4	0	1	66	66	1	2.09	1.00	1.00
32	PHOENX_A	2	5	0	1	62	63	1	1.54	1.07	0.82
33	AMRAAM	3	5	0	4	82	78	1	1.44	1.80	0.66
34	HELLFIRE	1	5	0	3	76	75	1	1.09	1.44	0.95
35	HARM	2	5	0	3	78	78	1	2.03	1.05	1.00
36	SPARRO_F	2	5	1	1	66	68	1	4.25	3.90	3.94
37	TOW	1	5	0	1	63	66	1	1.20	1.45	1.01
38	SDWNDER_L	2	5	1	2	71	71	1	4.89	2.45	4.10
39	TOW2	1	5	1	3	78	84	1	1.70	1.02	1.00
40	HARPOON	2	5	0	2	73	70	1	1.17	1.36	0.84
41	MVRICK_DG	3	5	1	3	76	75	1	1.07	1.98	0.94
42	SPARRO_E	2	5	1	1	60	69	1	0.84	1.00	1.00
43	SPARRO_M	2	5	1	3	78	78	1	0.98	1.46	1.00
44	SWNDR_M	2	5	1	3	76	89	1	2.04	1.01	1.94
45	PHOENX_C	2	5	1	3	77	77	1	1.67	1.45	1.50

PROGID	PROGRAM	SVC	EQTYPE	MOD	TIME	FSDS1	BASEYR	DEV2	DCG	DSG	DQG
46	ADDS	1	7	0	4	85	83	0	1.32	1.54	1.00
47	MLS	3	7	0	4	88	82	0	0.83	1.08	1.00
48	JTIDS	3	7	0	4	81	81	1	3.11	1.46	2.35
49	JSTARS	3	7	0	4	84	83	1	1.18	1.00	1.38
50	WIS	3	7	0	4	85	82	0	1.60	2.11	1.00
51	SINCGARS	1	7	0	3	78	84	1	1.35	1.29	1.98
52	ASPJ	2	7	0	4	81	84	1	2.36	1.69	1.00
53	LANTIRN	3	7	0	4	80	80	1	0.96	1.00	1.00
54	TRI_TAC	3	7	0	3	75	76	1	1.03	1.00	1.00
55	OTH_B	3	7	0	4	82	82	1	1.22	1.44	1.00
56	DMSP	3	0	0	3	76	75	1	1.00	1.00	1.00
57	NVST_GPS	3	0	0	3	79	79	1	0.99	1.44	1.00
58	DSP	3	0	0	1	67	78	1	1.35	1.00	1.00
59	DSCS3	3	0	0	3	76	77	1	2.54	1.59	1.00
60	ROLAND	1	6	1	3	75	75	1	1.52	2.15	1.00
61	IMPWAWK	1	6	1	1	64	89	1	1.87	1.25	1.00
62	SHELLAGH	1	6	0	1	59	64	1	1.31	1.05	1.38
63	MK_48_AD	2	6	1	4	82	86	1	1.01	1.35	1.00
64	MLRS	1	6	0	3	76	78	1	1.03	1.00	0.72
65	MK-50	2	6	0	4	83	84	1	1.27	1.29	1.00
66	STNGER_P	1	6	1	3	77	72	1	1.02	1.95	0.90
67	MK-48	2	6	0	1	68	72	1	1.83	0.89	0.57
68	STNGR_BA	1	6	0	3	75	72	1	1.46	2.46	0.73
69	COPPRHD	1	6	0	3	75	75	1	1.28	1.75	0.78
70	DIVAD	1	6	0	3	77	78	1	1.60	1.74	1.00
71	FIVEINCH	2	6	0	3	77	77	1	1.16	1.00	0.65
72	STNGER_R	1	6	1	4	84	72	1	1.02	1.18	1.50
73	DRAGON	1	6	0	1	66	66	1	1.88	2.14	1.05
74	PERSHNG2	1	6	1	3	79	79	1	1.00	0.83	0.82
75	PATRIOT	1	6	0	2	72	72	1	1.40	1.15	0.83
76	STD_MSL2	2	6	1	2	72	84	1	1.44	1.00	1.00
77	LANCE	1	6	0	1	67	70	1	1.08	1.46	1.09
78	PEACEKPR	3	8	0	3	78	82	1	0.96	1.00	1.00
79	GLCM	3	8	1	3	78	77	1	3.48	1.30	0.83
80	TOMAHAWK	2	8	1	3	77	77	1	1.66	1.48	0.91
81	SRAM_II	3	8	0	4	87	83	0	1.00	1.19	.
82	MINUTEM2	3	8	1	1	65	69	1	1.00	1.71	1.00
83	TRIDENT2	2	8	1	4	83	83	1	0.93	1.00	0.93
84	ICBM	3	8	0	4	86	84	0	0.31	1.00	0.14
85	ALCM	3	8	0	3	77	77	1	1.37	1.34	0.69
86	SRAM	3	8	0	1	66	66	1	2.80	2.03	.
87	MINUTEM3	3	8	1	1	66	67	1	0.98	0.87	0.73
88	CONDOR	2	5	0	1	66	70	1	1.72	3.00	1.19
89	MVRICK_A	3	5	0	1	68	68	1	1.15	1.46	0.91

PROGID	PROGRAM	PROD_U	PCG	PSG	PQG	TPCG	STRETCH
1	V-22	0	0.93	1.26	0.75	0.94	1.6800
2	T45TS	0	1.20	1.00	1.00	0.97	1.0000
3	B-1A	1	.	.	.	.	.
4	C-5B	1	0.77	0.99	1.00	0.76	0.9900
5	C-17A	0	1.01	0.92	1.00	1.04	0.9200
6	C-5A	1	2.15	1.19	0.66	1.77	1.8030
7	B-1B	1	0.95	1.00	1.00	0.95	1.0000
8	FB-111A	1	1.80	.	0.29	1.83	
9	AV-8A	1	0.99	1.00	0.96	0.99	1.0417
10	F-5E	1	0.79	.	1.79	0.88	.
11	F-15	1	1.20	3.38	1.74	1.16	1.9425
12	F-16	1	1.21	3.34	4.20	1.19	0.7952
13	F-14D	0	0.79	0.99	1.73	0.82	0.5723
14	F-14A	1	1.25	3.18	1.26	1.28	2.5238
15	AV-8B	1	0.77	1.27	0.82	0.82	1.5488
16	A-10	1	1.34	0.98	1.00	1.33	0.9800
17	F/A-18	1	1.42	1.71	1.45	1.37	1.1793
18	E-6A	1	0.92	.	1.07	0.96	.
19	E-3A	1	1.19	2.37	0.74	1.25	3.2027
20	EF-111A	1	1.62	1.86	1.00	1.73	1.8600
21	E-2C	1	1.22	.	2.32	1.28	
22	EA-6B	1	1.32	.	1.57	1.30	.
23	P-3C	1	1.35	0.80	0.48	1.42	1.6667
24	LAMPSMK3	1	1.17	1.89	1.00	1.13	1.8900
25	E-4	1	0.69	1.00	0.50	1.07	2.0000
26	S-3A	1	1.36	1.00	0.95	1.30	1.0526
27	CH-47D	1	1.35	0.99	1.21	1.33	0.8182
28	OH-58D	1	1.30	1.02	0.34	1.26	3.0000
29	UH-60A	1	1.25	1.00	1.00	1.22	1.0000
30	AH-64A	1	1.74	1.02	1.26	1.59	0.8095
31	CHEYENNE	0	.	.	.	.	.
32	PHOENX_A	1	1.35	1.20	0.98	1.39	1.2245
33	AMRAAM	0	1.05	1.11	1.00	1.06	1.1100
34	HELLFIRE	1	1.61	2.38	1.98	1.39	1.2020
35	HARM	1	1.39	1.61	1.05	1.47	1.5333
36	SPARRO_F	1	1.58	1.93	1.66	1.74	1.1627
37	TOW	1	1.78	2.27	0.59	1.70	3.8475
38	SDWNDER_L	1	2.07	2.76	1.23	2.25	2.2439
39	TOW2	1	0.95	0.94	0.89	0.98	1.0562
40	HARPOON	1	1.64	3.05	0.95	1.53	3.2105
41	MVRICK_DG	1	1.58	2.14	1.95	1.53	1.0974
42	SPARRO_E	1	1.08	3.11	0.34	1.07	9.1471
43	SPARRO_M	1	1.31	1.61	1.38	1.29	1.1667
44	SWNDR_M	1	1.01	2.44	2.27	1.10	1.0749
45	PHOENX_C	1	2.01	3.71	4.76	1.93	0.7794

PROGID	PROGRAM	PROD_U	PCG	PSG	PQG	TPCG	STRETCH
46	ADDS	0	.	.	.	.	.
47	MLS	0	.	.	.	.	.
48	JTIDS	0	.	.	.	.	.
49	JSTARS	0	.	.	.	.	.
50	WIS	1	.	.	.	.	.
51	SINCGARS	1	.	.	.	.	.
52	ASPJ	0	.	.	.	.	.
53	LANTIRN	1	.	.	.	.	.
54	TRI_TAC	1	.	.	.	.	.
55	OTH_B	1	.	.	.	.	.
56	DMSP	1	0.92	1.00	1.13	0.95	0.8850
57	NVST_GPS	1	1.24	2.08	1.71	1.08	1.2164
58	DSP	1	1.00	1.20	1.47	1.06	0.8163
59	DSCS3	1	1.75	1.17	1.08	1.99	1.0833
60	ROLAND	1	4.80	0.80	0.15	4.17	5.3333
61	IMPHAWK	1	3.07	3.16	1.49	1.48	2.1208
62	SHELLAGH	1	1.51	1.44	0.89	1.45	1.6180
63	MK_48_AD	0	1.91	0.91	1.00	1.73	0.9100
64	MLRS	1	0.94	1.49	1.27	0.95	1.1732
65	MK-50	0	1.02	0.86	1.00	1.08	0.8600
66	STNGER_P	1	.	.	.	.	.
67	MK-48	1	1.00	1.59	0.68	1.08	2.3382
68	STNGR_BA	1	1.81	2.24	2.20	1.75	1.0182
69	COPPRHD	1	2.23	1.03	0.19	2.12	5.4211
70	DIVAD	1	2.39	0.63	0.10	2.33	6.3000
71	FIVEINCH	0	0.22	.	0.44	1.93	.
72	STNGER_R	0	.	.	.	.	.
73	DRAGON	1	2.72	1.13	0.27	2.60	4.1852
74	PERSHNG2	1	2.31	1.46	0.71	1.67	2.0563
75	PATRIOT	1	1.78	1.00	0.44	1.67	2.2727
76	STD_MSL2	0	0.91	1.67	1.36	0.96	1.2279
77	LANCE	1	1.20	1.86	2.00	1.12	0.9300
78	PEACEKPR	1	1.51	1.90	1.05	1.28	1.8095
79	GLCM	1	1.62	1.30	0.80	1.67	1.6250
80	TOMAHAWK	1	1.50	1.46	3.69	1.57	0.3957
81	SRAM_II	0	0.69	1.04	1.00	0.81	1.0400
82	MINUTEM2	1	1.24	1.00	1.00	1.06	1.0000
83	TRIDENT2	0	1.01	1.31	1.15	0.97	1.1391
84	ICBM	0	.	.	.	.	.
85	ALCM	1	1.18	1.69	0.51	1.17	3.3137
86	SRAM	1	5.53	1.25	2.14	3.39	0.5841
87	MINUTEM3	1	1.69	1.14	1.13	1.39	1.0089
88	CONDOR	1	6.61	1.12	0.02	5.19	56.0000
89	MVRICK_A	1	0.84	.	1.18	0.95	.

PROGID	PROGRAM	PRO	C_PRD	DTC	MYP	FPD	TPP	I_FSD	I_PRD
1	V-22	1	0	0	0	1	0	1	0
2	T45TS	1	0	0	0	1	0	0	0
3	B-1A	0	0	0	0	0	0	1	1
4	C-5B	1	0	0	0	0	0	0	0
5	C-17A	0	0	0	0	0	0	1	0
6	C-5A	0	0	0	0	0	1	1	1
7	B-1B	1	0	0	1	0	0	0	1
8	FB-111A	1	0	0	0	0	0	0	0
9	AV-8A	1	0	0	0	0	0	0	0
10	F-5E	1	0	0	0	0	0	1	1
11	F-15	0	0	0	0	0	0	1	1
12	F-16	1	0	1	1	0	0	1	1
13	F-14D	0	0	0	0	1	0	0	0
14	F-14A	0	0	0	0	1	0	1	0
15	AV-8B	1	0	1	0	0	0	1	1
16	A-10	1	0	1	0	0	0	1	1
17	F/A-18	1	0	1	0	0	0	1	1
18	E-6A	1	0	0	0	1	0	0	0
19	E-3A	1	0	0	0	0	0	1	1
20	EF-111A	0	0	1	0	0	0	1	0
21	E-2C	0	0	0	0	0	0	1	0
22	EA-6B	0	0	0	0	0	0	0	0
23	P-3C	1	0	0	0	0	0	1	1
24	LAMPSMK3	1	0	1	0	0	0	1	1
25	E-4	0	0	0	0	0	0	1	0
26	S-3A	0	0	0	0	0	0	1	1
27	CH-47D	0	0	1	1	0	0	0	1
28	OH-58D	0	0	1	0	0	0	1	0
29	UH-60A	1	0	1	1	0	0	1	1
30	AH-64A	1	0	1	0	0	0	0	1
31	CHEYENNE	1	0	0	0	1	0	0	0
32	PHOENX_A	1	0	0	0	0	0	0	1
33	AMRAAM	1	1	1	0	1	0	0	0
34	HELLFIRE	1	1	1	0	0	0	1	0
35	HARM	1	0	1	0	0	0	1	1
36	SPARRO_F	1	1	0	0	0	0	1	1
37	TOW	1	1	0	1	0	0	0	1
38	SDWNDER_L	0	1	1	0	0	0	1	1
39	TOW2	0	0	0	0	0	0	1	1
40	HARPOON	1	0	1	0	0	0	1	1
41	MVRICK_DG	1	1	1	0	0	0	1	1
42	SPARRO_E	1	0	0	0	0	0	1	1
43	SPARRO_M	1	1	1	0	0	0	1	1
44	SWNDR_M	0	1	1	0	0	0	0	0
45	PHOENX_C	1	1	0	0	0	0	1	1

PROGID	PROGRAM	PRO	C_PRD	DTC	MYP	FPD	TPP	I_FSD	I_PRD
46	ADDS	1	0	0	0	0	0	0	0
47	MLS	0	0	0	0	0	0	0	0
48	JTIDS	1	0	0	0	1	0	0	0
49	JSTARS	0	0	0	0	0	0	1	1
50	WIS	0	0	0	0	0	0	1	0
51	SINCGARS	1	1	0	0	0	0	0	0
52	ASPJ	1	0	0	0	0	0	0	0
53	LANTIRN	1	0	0	0	0	0	0	0
54	TRI_TAC	0	0	0	0	0	0	0	0
55	OTH_B	1	0	0	0	0	0	0	1
56	DMSP	0	0	0	1	0	0	1	1
57	NVST_GPS	0	0	1	1	0	0	1	0
58	DSP	0	0	0	1	0	0	1	1
59	DSCS3	0	0	1	1	0	0	1	0
60	ROLAND	1	0	0	0	0	0	1	1
61	IMPHAWK	0	0	0	0	0	0	1	1
62	SHELLAGH	0	1	0	1	0	0	1	1
63	MK_48_AD	0	1	0	0	0	0	1	1
64	MLRS	1	0	1	1	0	0	0	1
65	MK-50	1	1	1	0	0	0	1	0
66	STNGER_P	0	0	1	0	0	0	1	1
67	MK-48	0	0	0	0	0	0	1	1
68	STNGR_BA	0	1	1	0	0	0	1	1
69	COPPRHD	1	0	1	0	0	0	0	1
70	DIVAD	1	0	1	0	0	0	1	1
71	FIVEINCH	0	0	1	0	0	0	1	0
72	STNGER_R	0	0	1	1	1	0	1	1
73	DRAGON	0	1	0	0	0	0	0	0
74	PERSHNG2	0	0	1	0	0	0	1	0
75	PATRIOT	0	0	1	1	0	0	1	1
76	STD_MSL2	0	1	0	0	0	0	1	1
77	LANCE	0	0	0	0	0	0	1	1
78	PEACEKPR	0	0	0	0	0	0	1	1
79	GLCM	1	0	0	0	0	0	0	0
80	TOMAHAWK	1	1	0	0	0	0	0	0
81	SRAM_II	0	0	0	0	0	0	1	1
82	MINUTEM2	0	0	0	0	0	0	1	1
83	TRIDENT2	0	0	0	0	0	0	1	1
84	ICBM	1	0	0	0	0	0	1	0
85	ALCM	1	0	1	0	0	0	1	1
86	SRAM	0	0	0	0	0	1	0	0
87	MINUTEM3	0	0	0	0	0	0	1	1
88	CONDOR	1	0	1	0	0	0	1	1
89	MVRICK_A	1	0	0	0	0	1	0	0

Appendix B

UNANTICIPATED INFLATION

APPENDIX B
UNANTICIPATED INFLATION

In programs of long duration (typically over 10 years), changing economic conditions become a substantial challenge in program planning. Our measures of cost growth are calculated in base-year dollars, as reported by the services. However, we are also interested in how inflation affects program planning. Program managers typically project spending in real terms and then add an inflation factor. Incorrect predictions of inflation can result in program overfunding or underfunding--an "inflation dividend" or "inflation deficit."

For very early programs, the impact of inflation on the program was exceedingly difficult to trace. In a few cases, the first SARs reported what were apparently then-year dollars, and made no attempt to convert into constant dollars. Occasionally, cryptic references to escalation factors were made. As program management became more institutionalized, procedures for inflation planning improved. Escalation factors were built into program plans. These factors were calculated based on price proxies and assumed spend-out rates.

In times of unanticipated high inflation, programs may end up underfunded in real terms. For example, inflation in the procurement accounts for the period 1978-81 totaled 45 percent, while only 28 percent was budgeted [B-1]. Thus, obligational authority planned on reasonable inflation rates was inadequate to meet needs in times of very high inflation.

As a result of concern over underfunding, Congress permitted the Defense Department to add 30 percent to the projected inflation rate for major weapon systems for the period, 1982-88. However, this overcompensated for the problem. In the early 1980s, inflation declined below planned levels. Even programs funded according to projected inflation were overfunded.

Thus, concern shifted the other way, towards overfunding. If programs receive funding based on very high inflation projections and these projections do not prove true, then programs have more resources than required in real terms. This so-called "inflation dividend" has attracted considerable controversy in recent years. Congress has become increasingly concerned about tracking down instances of overfunding and correcting them. The General Accounting Office and the Congressional Budget Office have published reports on the subject [B-1 through B-3]. However, some of the inflation dividends are cut by congressional action or returned to the Treasury.

In order to get some sense of the magnitude of the inflation dividend problem, we used a method of evaluating inflation dividends and deficits based on work done by the Congressional Budget Office [B-3]. We developed a spreadsheet version of this model and developed input data for the category of Air Force missiles.

The following percentage coefficients (see Table B-1) hold for any Air Force missile programs. These are based on the difference between the budget request year and actual inflation. A positive sign represents an inflation dividend, while a negative sign represents an inflation deficit.

Table B-1. Inflation Dividend/Deficit Coefficients for Air Force Missile Programs

FY	Coefficient
1981	-3.26343
1982	-3.0953
1983	2.43042
1984	3.59823
1985	5.97986
1986	4.728131
1987	1.197126
1988	-.062109

Note that these coefficients are for estimates made essentially one year in advance. For estimates made four or five years in advance, as the Five-Year Defense Plan is, these estimates would cumulate. And for a hypothetical Air Force missile program with FSD in 1981, planning for FY 1988 funding is extremely difficult. A "real" million dollars in funding planned for in FY 1980 would translate to 1.10673 million in FY 1988 due to cumulated inflation dividends and deficits.

It is also important to note that these coefficients are based on the deflator for Air Force missiles and not on deflators used in the SARs. A General Accounting Office (GAO) study [B-2] found a serious lack of uniformity in reporting of inflation in the SARs. The index used for adjusting inflation in prior years was sometimes an industry-specific index and sometimes the GNP deflator. In addition, the number of years for which prior-year adjustments were reported in the "current economic change" line of the cost variance analysis varied. The GAO cautions that these differences cannot be tracked without examining individual worksheets.

We consider here the implications for program evaluation and for the budgeting process. In terms of program evaluation, it would be interesting to know how much impact mis-estimates of inflation had on estimates of program cost growth. However, this is very difficult to determine, because, at least for historical SARs, it is rare to see a complete annual funding plan at FSD. Our hypothetical example gives a general idea of magnitudes.

When one considers a budget for the whole set of major programs, in a particular year, a serious mis-estimate of inflation can make a substantial difference. Better methods of tracking such surpluses or deficits are needed in order to allow defense to get its fair share relative to other needs. The crux of the problem is that program accounting is generally done in constant dollars, while Congress budgets in current dollars.

It would be useful for the Defense Department to develop and enforce clear uniform standards for reporting inflation on the SARs. While the amounts involved are such that they seem small to a program manager, Congress is extremely sensitive to these differences. Thus, it makes sense to track inflation dividends or funding shortages on a regular basis.

REFERENCES

[B-1] U.S. Congressional Budget Office. "Report on Inflation." 1988.

[B-2] U.S. General Accounting Office. "Budgeting and Monitoring Inflation Funding in the Department of Defense." April 1988.

[B-3] U.S. Congressional Budget Office. "Budgeting for Defense Inflation." January 1986.

Appendix C

MULTI-YEAR PROCUREMENT CASE STUDIES

APPENDIX C
MULTI-YEAR PROCUREMENT CASE STUDIES

A. MULTIPLE LAUNCH ROCKET SYSTEM (MLRS)

The MLRS multi-year contract was awarded to LTV in September 1983 following a should-cost analysis. The Army claimed a cost savings through MYP contracting of $193.4, or 11.5 percent of the anticipated cost of $1,877.1 million for five annual contracts. The savings were said to be primarily due to advance purchasing of materials. The contract was a five-year firm-fixed-price contract with an economic-price-adjustment clause and a negotiated option for FY 1988 and 1989. The multi-year contract, with options, covers all self-propelled launchers/loaders and rockets and selected high-cost spare parts for the life of the program as approved at that time.

The Army was confident that MLRS met the criteria for selection as an MYP program. The requirement for MLRS was strong, as the Army desperately needed a modern, heavy artillery piece. There were indications that MLRS would be acceptable to the NATO allies for their requirements. At the time of the MYP proposal, MLRS was fully-funded in the approved FYDP at levels that would support the MYP strategy. The MLRS design is relatively simple, incorporating previously applied technology such as the Bradley Fighting Vehicle chassis and drive train. Risk of cost growth was considered to be low because the system was developed competitively (cost proposals from both contractors were very similar), because of the simplicity of the design and because selected design tradeoffs had been made during the development of the system.

The only data available to IDA for examination of cost savings due to use of an MYP acquisition strategy were the MLRS program SARs and the IDA database (developed for macro-analysis). The program funding summary information provided in the SAR does not segregate the funding for launchers and rockets. We decided not to use such general funding data to estimate the prices of annual contracts parametrically, as the results varied significantly when the quantities of launchers or quantities of rockets were used.

We were able to extract flyaway costs reported in each of the MLRS program SARs and develop a picture of program cost performance to date, including unit cost trends for the launcher and rocket. An overview of the MLRS program performance is presented as Table C-1. The unit price performance for the launcher and rocket are presented as Figures C-1 and C-2 [C-1].

Table C-1. MLRS Procurement Quantities and Average Unit Costs

System/Subsystem	SARs June 1979	SARs December 1987	Percent Change
Tactical Rockets			
Quantity	362,832	452,322	+21.4
Unit Price (K1978$)	$4.48	$ 3.22	−28.1
Training Rockets			
Quantity	27,648	45,060	+63.0
Unit Price (K1978$)	$3.54	2.79	−21.2
SPLLs			
Quantity	173	592	+242.2
Unit Price (K1978$)	$687.3	$984.6	+36.0

Note: Unit costs are based upon flyaway costs reported in the indicated SARs.

Table C-1 presents a program cost history that is inconclusive. Our general analysis of the program for the IDA database resulted in estimated production cost savings of six percent and estimated total program cost savings of 5 percent for the MLRS program (see Table VI-2). We did not segregate the MYP years from prior years for the general analysis. The unit cost trends shown in Figures C-1 and C-2 for the multi-year period indicate cost savings during the MYP period were higher than experienced by the program as a whole. The SARs present a picture of steadily decreasing unit costs for MLRS launchers and rockets during the period of the MYP contract, FY 1983-87.

Factors other than MYP that may also have contributed to production cost containment for MLRS are:

- The program estimate of quantities of launchers and rockets to be procured increased substantially over the period of the MYP contract.
- The current MLRS launcher and rocket incorporate relatively simple technology, providing a good foundation upon which newer technologies can be applied for terminally guided warheads. The Army was willing to accept performance somewhat less than planned to field a system relatively quickly in order to fill a significant deficiency.

- Perhaps most importantly, MLRS has enjoyed strong support both within the military and the Congress. A factor in this stability may have been the multi-national nature of the program.

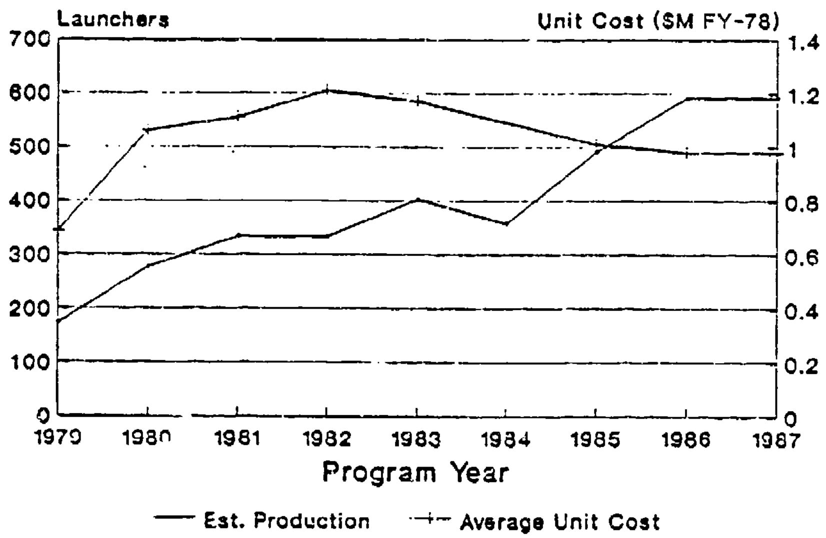


Figure C-1. MLRS Launcher Unit Price and Quantity

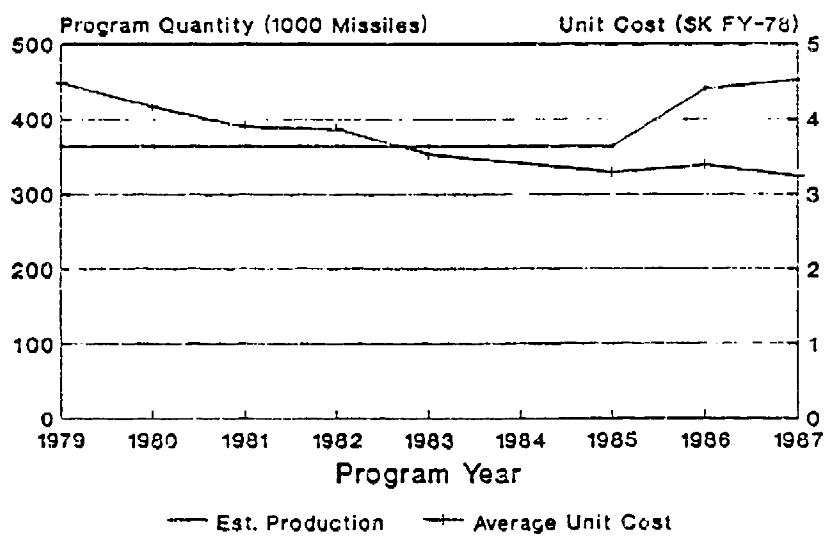


Figure C-2. MLRS Rocket Unit Price and Quantity

It is likely that use of an MYP procurement strategy contributed to the cost performance of the MLRS program. An assessment of the MLRS multi-year contract was conducted by the GAO [C-2]. The GAO estimated savings due to MYP to be $166.8 million. The GAO assessment was based on proposal data that LTV received from its major subcontractors. The estimated savings were due to purchasing certain raw materials and components earlier, and in more economic quantities, than would have been done under annual contracts.

B. UH-60 HELICOPTER AIRFRAME

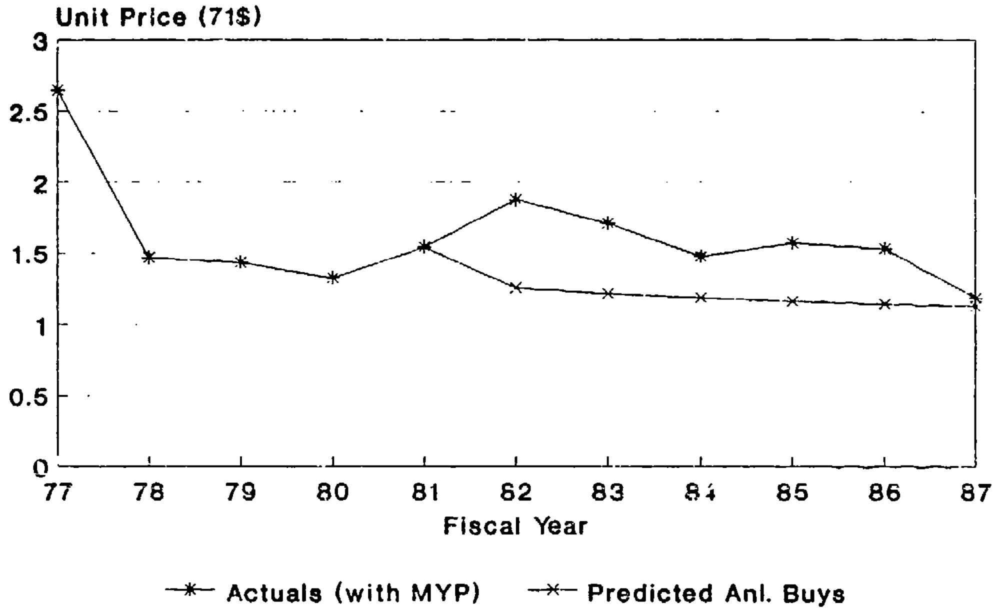
The U.S. Army has proposed the UH-60A Black Hawk helicopter airframe as a candidate for multi-year contracting in FY 1982-84, FY 1985-87, and FY 1988-91. The Army estimated cumulative savings from the MYP strategy over the period FY 1982-87 to be $177.9 million on multi-year contracts valued at $1,959.1 million. Projected savings for the FY 1982-84 contract were $75.4 million, or 7.5 percent, of the $1,006.6 million estimated value of three annual contracts. A total of 276 aircraft were to be procured. Based on a comparison of three single-year cost estimates to multi-year cost estimates for 234 aircraft over the period FY 1985-87, the Army estimated cost savings at approximately $102 million, or 9 percent of $1,130.4 million for single year contracting.

The Army and the GAO, in their independent assessment, generally agreed that the UH-60 met the criteria for selection as an MYP program. The procurement objective for the UH-60A Black Hawk aircraft since inception of the program in 1971 has been 1,107. In the December 1987 SAR the procurement objective was increased to 1,111 aircraft. The funding for the program is assured because the UH-60A Black Hawk is a stable, high-priority system. The UH-60 program SARs show FYDP support for the FY 1982-84 and FY 1985-87 MYP contracts has been stable. Research and Development (R&D) on the UH-60A Black Hawk airframe are complete. Five single year airframe contracts (FY 1977-82) and three multi-year airframe contracts (FY 1982-84, FY 1985-87, FY 1988-91) have been awarded.

GAO reviews of the UH-60 MYP contracts cited circumstances occurring during the FY 1985-87 MYP that would affect the validity of the Army estimates of MYP savings.

- In their September 1986 assessment of the FY 1988-91 MYP proposal, the GAO was concerned that the Army had not demonstrated a strong commitment to protect the projected funding profiles of the UH-60 [C-3].
- Product improvements were being performed that involved over 200 modifications to the helicopter [C-4].

The recurring price data contained in the UH-60 program funding summary of the December 1987 SAR were examined in an attempt to determine the effect of the MYP contracts on the program. Only actual price data from FY 1977-87 were used in the analysis. The prices for annual buys in FY 1982-87 were estimated parametrically using the price data available for the years where annual contracts were used, FY 1977-81. A comparison of unit price differences under the multi-year and annual contracting scenarios is presented in Figure C-3.



Source: 12/87 UH-60 SAR.

Figure C-3. UH-60 Helicopter MYP Analysis

The predicted average recurring unit price for aircraft procured using annual contracts during the period of the two MYP contracts is $1.18 million in FY 1971 dollars. This is 21 percent less than the $1.49 million average recurring unit cost of aircraft procured under the multi-year contracts. Total cost for the 522 aircraft procured during that period is estimated as $618.5 million compared to the actual price of $820.3 million for aircraft under MYP.

The data on which the predicted annual prices were estimated represent the UH-60A without the product improvements mentioned above. The actual MYP unit prices and the predicted annual unit prices could represent significantly different aircraft. Data were not available to IDA to adjust the FY 1977-81 annual buys to reflect the product improvements incorporated later. The Army stated in the MYP justifications that product improvements were considered in the estimates of savings from pursuing an MYP strategy. The Army estimates of savings cannot be supported by the data available.

A GAO study also indicates that the UH-60A helicopter FY 1986-88 multi-year contract unit price of $3.02 million is $71,000 (2.4 percent) higher than the annual contract unit price for the preceding year and $26,000 (9.4 percent) higher than the average price for the prior 2 years. The GAO attributes the price increase to the 200 modifications made to the helicopter. The increases occurred despite a $32 million price reduction (then-year dollars) through the economic price adjustment clause and a $26 million savings (then-year dollars) from accelerated aircraft deliveries. Another factor cited by the GAO, which may have contributed to the increase in the unit price for the UH-60A helicopter, is that the production contract for fiscal year 1979 was negotiated after a competitive research and development phase between two contractors. The multi-year contract was awarded after a proposal from only one contractor [C-4].

C. CH-47D HELICOPTER MODIFICATION

The Army is modernizing 240 CH-47 aircraft using an MYP contract for FY 1985-89. The Army, in its multi-year justification, estimated the cost of the FY 1985-89 MYP contract as $1,281.4 million. Cost savings from using the MYP approach were estimated to be $153.4 million, approximately 12 percent of the cost for a series of annual contracts for the same period and the same quantity of CH-47D aircraft.

The CH-47D program clearly met the criteria for selection as an MYP program:

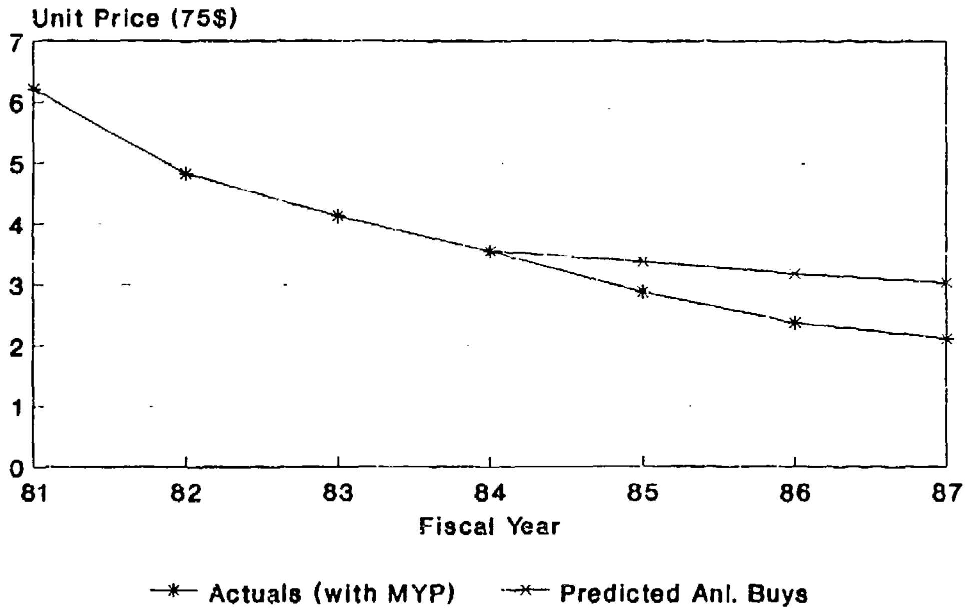
- The Army procurement objective for the CH-47D has remained constant since 1979 and no follow-on aircraft is in development. The CH-47 is the Army's only medium-lift helicopter. It supports Army operations worldwide and was initially fielded with the Rapid Deployment Force in 1983.
- Available SAR data show funding for the CH-47D program has been consistently supported in the President's Budget and the FYDP. Since December 1980, the airframe unit acquisition cost of the CH-47D program has maintained a downward trend.
- The MYP contract is the fifth production contract, and the CH-47D production design is frozen. There are no sophisticated, high-risk technology subsystems on the aircraft. Technical and performance objectives have been met or exceeded and no significant changes are planned or anticipated.

The Army cost estimates in the justification for MYP were based on cost information from prior design-to-unit cost and design-to-unit production cost exercises, production actuals from earlier models of CH-47, the estimates of two should-cost teams, and the negotiations of four annual production contracts on the CH-47D program.

There is no question that the CH-47D producer has the ability to continue to successfully remanufacture the helicopter:

- The contractor has provided over 900 CH-47s to date, over 200 overhauls, and combat damage or accident repairs have been made.
- Three prototype aircraft were delivered on cost and ahead of schedule.
- Four single-year airframe contracts (FY 1981-84) have been a /arded.
- Four single-year engine contracts (FY 1980-81) have been awarded.
- All of these contracts have been executed within cost and schedule.

As shown in Figure C-4, cost performance (measured in terms of the differences in average unit price) has been significantly better under the MYP strategy than we estimate it would have been if a series of annual contracts had been let. To date, 144 aircraft have been procured for $353.5 million under the MYP contract. Recurring average unit price is $2.45 million for that time period. The estimated cost for three annual contracts at the same quantity is $460.6 million. Average unit price is $3.20 million.



Source: 12/87 CH-47D SAR.

Figure C-4. CH-47D MYP Analysis

D. DSCS III Satellite

The purchase of seven Defense Satellite Communications System (DSCS) III spacecraft with a multi-year procurement contract in FY 1985-88 was approved by Congress. The DSCS III multi-year contract was projected to save $175.8 million (in then-year dollars) or 19.8% over an annual buy at the same production rate, across four years of procurement.

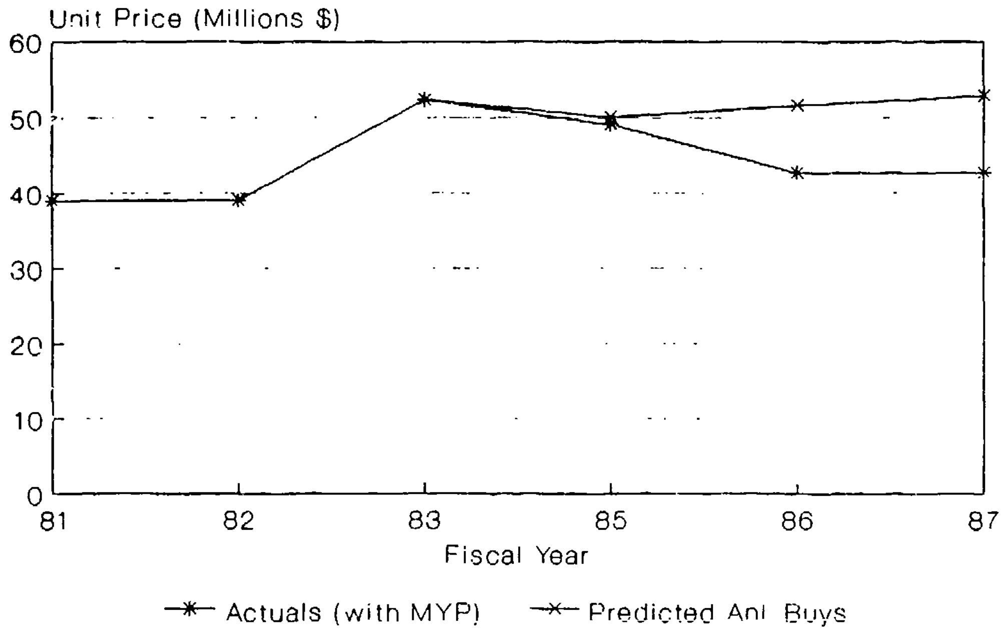
In early 1976, the Air Force made a decision to develop a DSCS III to provide increased capabilities. A firm requirement for 12 production DSCS III spacecraft was established in 1978 by the Defense Communication Agency (DCA) to replace the DSCS II system. The DSCS III production rate was stabilized when OSD approved the production of DSCS III in December 1981. The first production contract was awarded in January 1982 and was preceded by an advance parts buy a year earlier. The first five production spacecraft contain improvements approved by the Deputy Secretary of Defense in December 1981. The first development flight satellite was launched in October 1982 and successfully completed on-orbit testing. By 1984, all of the first five DSCS III satellites were on contract via annual buy contracting. The multi-year contract procures the seven remaining spacecraft in the Air Force procurement plan. The seven satellites have no basic design changes from the five bought on annual contract.

Data available from DSCS III program SARs show the Five Year Defense Plan (FYDP) has consistently maintained funding to support the DSCS III program. The Air Force, OSD, DCA, other government agencies, and the Congress are committed to the DSCS III program. There were no alternative spacecraft to perform the DSCS mission, providing critical national communications support through the 1990s.

Air Force estimates of cost savings from MYP were based upon the annual production contracts and were consistent with actual production experience. Anticipated economies of production were included in the MYP estimates. Although the contractor experienced cost growth problems in the initial stages of the development contract, contractor performance was within negotiated costs and on schedule during the annual buys preceding the MYP contract.

As shown in Figure C-5, cost performance has been substantially better under the MYP strategy than we estimate it would have been had annual procurements been continued. As of December 1987, 6 of 7 satellites have been procured for $269.0 million--

$44.8 million per copy. The estimated cost for three annual contracts to buy 6 satellites is $309 million, or a unit price of $51.5 million.



Source: 12/87 DSCS III SAR.

Figure C-5. DSCS III Satellite MYP Analysis

E. F-16 AIRCRAFT

The Air Force proposed, and received approval from OSD and Congress to purchase 480 F-16 aircraft in FY 1982-85 and 720 aircraft in FY 1986-89. Estimated cost savings were $246 million on a total contract price of $2,938 million for the FY 1982-85 MYP contract. The savings were estimated to be $358.3 million on an FY 1986-89 contract valued at $3,895.2 million. Savings were estimated to be 8 percent for the FY 1982-85 MYP contract and 8.4 percent for the FY 1986-89 contract.

The requirement for the F-16 has always been strong. Because of the requirement, the F-16 procurement objective has remained relatively stable over the life of the program. At the time of the first MYP proposal, the approved F-16 program was 1,388 aircraft. Six hundred and five had already been approved and procured through annual contracts. The FY 1981 FYDP contained funding for the approved 1,388 aircraft.

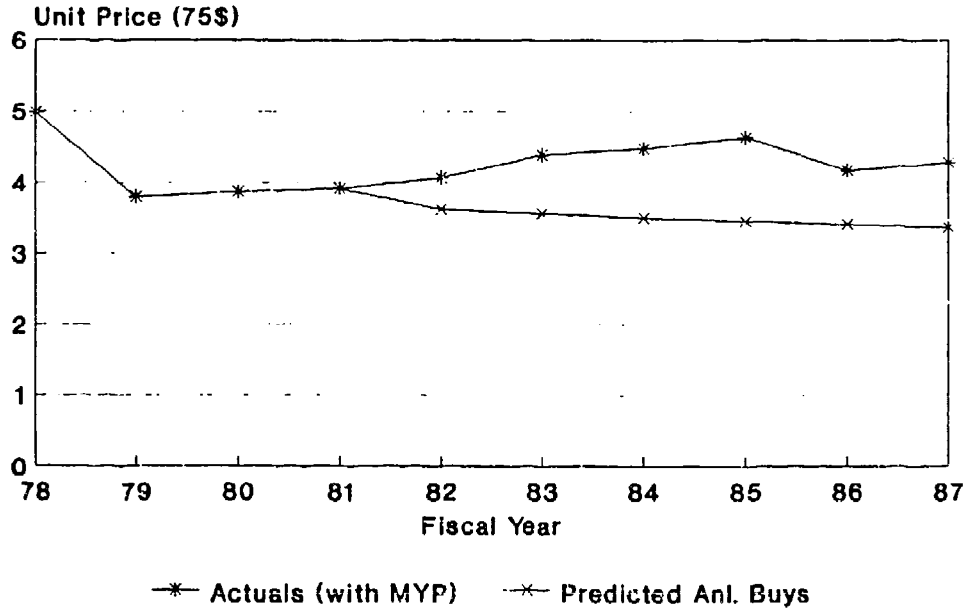
In early 1980, the Air Force made a decision to improve the configuration of the F-16 to provide capabilities considered to be essential in countering the projected threat in the mid-to-late 1980s. The management of this configuration change was formalized by the Multi-Staged Improvement Plan (MSIP). The cost implications of this program, and later changes that resulted in the F-16C and D models, were said to be included in the FY 1982-85 and FY 1986-89 multi-year contract proposals in the OSD multi-year justifications.

In March 1981, General Dynamics submitted alternative proposals to the Air Force on an annual and a multi-year basis for the FY 1982-85 period. The annual proposals assumed 120 aircraft per year would be procured under four annual contracts. General Dynamics estimated savings through the multi-year approach of $325.8 million. The Air Force adjusted the General Dynamics' proposal to add the effects of planned improvements. The adjustments increased the estimated savings from a multi-year contract to $350 million. The Air Force then recomputed the savings estimate based on inflation rates of 7 percent rather than the 9 percent previously used. The resulting estimated savings of $246 million was then submitted to Congress as part of the October 1981 Air Force multi-year justification package.

During the FY 1986-89 contract period, no further basic design changes were planned for the F-16. This multi-year program provides only for F-16C and D models. The Air Force believed that had the F-16E Dual Role Fighter been selected, the high degree of common parts would ensure continued configuration stability and sustain anticipated savings. Estimated savings of $358.3 million due to an FY 1986-89 multi-year procurement were submitted with the Air Force FY 1985 justification package.

The recurring price data contained in the F-16 program funding summary of the December 1987 SAR were examined in an attempt to determine the effect of the MYP contracts on the program. Only actual price data from FY 1978-87 were used in the analysis. The prices for annual buys in FY 1982-87 were estimated parametrically using the price data available for the years where annual contracts were used, FY 1978-81. A comparison of unit price differences under the multi-year and annual contracting scenarios is presented in Figure C-6.

The predicted average recurring unit price for aircraft procured using annual contracts during the period of the two MYP contracts is $3.48 million in FY 1975 dollars. This is 20 percent less than the $4.34 million average recurring unit cost of aircraft procured under the multi-year contracts. Total cost for the 894 aircraft procured during that period is estimated as $3,107.5 million compared to the actual price of $3,878.6 million for aircraft under MYP.



Source: 12/87 F-16 SAR.

Figure C-6. F-16 MYP Analysis

We could not conclude that use of MYP has been a failure in the F-16 program. The data on which the predicted annual prices were estimated represent F-16A and B model aircraft. Costs reflecting the additional complexities incorporated during the MSIP and F-16C and D model improvements. The actual MYP unit costs and the predicted annual unit costs probably represent very different aircraft. Data were not available to IDA (e.g., MSIP upgrade package costs) with which the FY 1978-81 annual buys could be adjusted to reflect the greater complexities of aircraft bought later. It may be that the Air Force bought additional quality at the expense of the anticipated savings from using an MYP strategy; however, the Air Force stated in the justifications for pursuing an MYP strategy that the costs of the MSIP and F-16C and D model updates had been considered in estimating savings from MYP. Regardless, the Air Force estimates of savings cannot be supported by the data available.

The GAO also concluded that data did not exist to validate the overall cost savings of the F-16 MYP contracts [C-5]. A GAO present value analysis of the same contractor estimates provided to the Air Force for the FY 1982-85 proposal indicated potential savings of $170.4 million, or 7.2 percent. In another study the GAO concluded that an F-16 unit price of $4.66 million for the FY 1982-85 MYP contract was 1.7 percent less than the preceding annual contract unit price and 2.7 percent less that the average price for the prior two annual contracts [C-4]. However, the GAO did not feel that either of these estimates were conclusive.

F. M1A1 TANK CHASSIS

An Army proposal to procure 3,299 M1 tank chassis through a MYP contract for FY 1986-89 was approved by OSD and the Congress. The Army proposal specified a maximum annual rate of 840 chassis, with options to reduce the procurement to a core program of 720 chassis per year. An option for an additional year's procurement of 419 chassis in FY 1990 was also included to maintain the 3,299 quantity. The Army estimate of potential savings for the core program as $403.1 million on an MYP buy of $3,969.2 million. This represents a 9.2 percent savings on the $4,372.3 million price tag for four single-year contracts.

The Army was confident that production rates for the M1 chassis would be stable. The Army's requirement for the M1 tank was stable. The M1 Basis of Issue plan called for 7,467 tanks at the time the MYP contract was proposed. A total of 4,168 tanks had been procured using annual contracts through FY 1985. The FY 1986-89 MYP contract allowed procurement of the remaining 3,299 tanks at the established rate of 70 per month (840 per year). The GAO was less certain that the planned production rates could be maintained [C-6]. Recognizing the uncertainty, the Army had proposed alternative multi-year contracts at a rate of 70 per month and the core program presented here of 60 per month (720 per year). The Army also was considering production rates for FY 1987-91 as low as 50 per month.

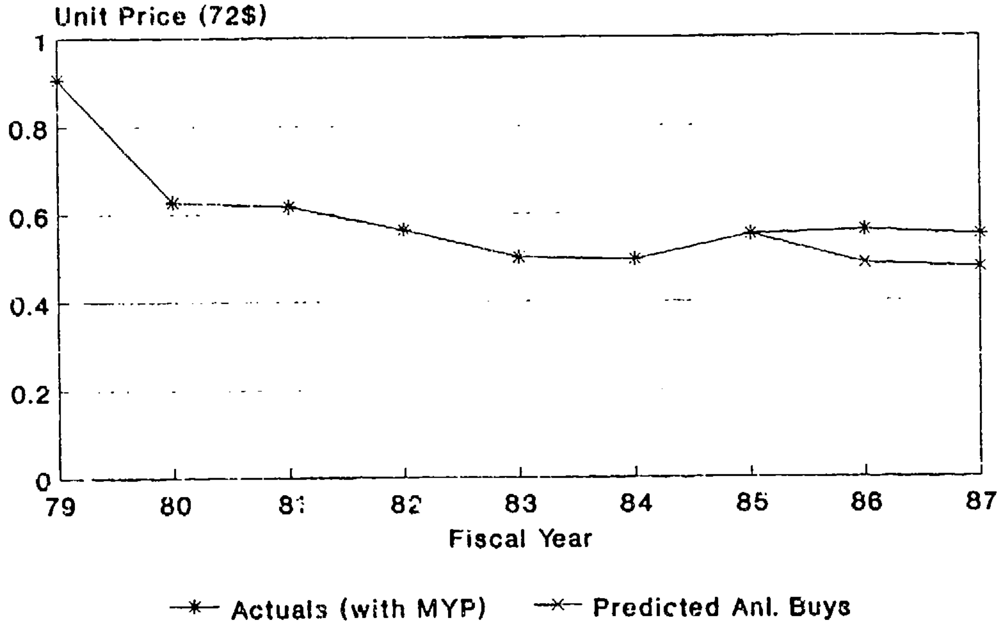
The Army stated that the M1 chassis would be funded at the required level throughout the MYP contract period. Funding for other programs would be delayed or cancelled if necessitated by reductions to the President's budget. The Army's acquisition strategy permitted a reduction from 840 to 720 chassis per year without breaching the MYP contract.

The M1A1 tank is an upgraded version of the basic M1 tank that had been in production for five years. The chassis is the M1A1 tank excluding armament, communication equipment, fire control equipment, suspension, and power train components. The M1A1 version of the tank completed operational testing in April 1984. Prior production of the basic M1 tank was about 2,500 units. Changes from the M1 to the M1A1, to be incorporated during the MYP contract, are being made in two blocks. Block I improvements included: a 120mm gun; an enhanced fire control system; an integrated nuclear, biological, chemical system; and modified transmission, final drive, and road wheels. Block II changes primarily affect the chassis. They are classified changes that had not been fully identified or tested at the time the MYP contract was proposed. The Block II changes involved an estimated $100,000 per chassis and included commander weapons station codifications, driver's all-weather viewer, improved track, and improved wiring harness. The Army anticipated Block II changes to have only minimal impact on the M1A1 configuration, and on the estimated savings from the MYP strategy. However, reassessment of the threat posed by Soviet tanks and anti-armor missiles since the MYP contract was let has resulted in configuration changes greater than planned. These additional configuration changes are being incorporated during the MYP period.

The Army was confident that multi-year estimates in the justification package were achievable. The GAO expressed certain concerns. The justification package cost estimate was prepared by the Army without firm contractor proposals on a multi-year and annual basis. The planned configuration changes and lack of production history for the M1A1 version of the tank and the uncertainty of future production rates all could contribute to further cost uncertainty.

We used the funding program summary available in the December 1987 SAR in order to estimate an average recurring unit price for the first two years of the MYP contract and for alternative annual contracts. The predicted unit prices for alternative annual contracts are based on the actual funding for the annual contracts that preceded the FY 1986 MYP contract. Plots of the M1 average recurring unit prices are shown on Figure C-7. Note that the predicted annual buys for FY 1986 and FY 1987 indicates a lower average unit cost than experienced under the MYP contract, $.48 million versus $.51 million. Costs for the first two years of MYP were $821.4 million. Estimated cost for two additional annual contracts is $774.1 million.

Two factors are likely to have produced this result. The Block II configuration changes and the unanticipated changes underway because of re-evaluation of the threat had a larger impact on unit price than the Army had anticipated. The data on which the predicted annual prices were estimated represent the basic M1 chassis. We were not able to adjust this data to reflect the greater complexity of the M1A1. However, the Army stated in its justification package that costs of incorporating the anticipated M1A1 improvements had been included in the estimated cost savings under MYP. It is likely cost growth experienced during the recent years of the M1 program are due to the unanticipated major configuration changes mentioned above. The available data do not support the 9.2 percent cost savings predicted for the M1A1 MYP contract.



Source: 12/87 M1 SAR.

Figure C-7. M1A1 Tank Chassis MYP Analysis

G. T700 ENGINE

The U.S. Army proposed the T700 series engines as candidates for multi-year contracting in FY 1983-1985 and FY 1986-88. Both proposals were approved by OSD and the Congress. The Army estimated an FY 1983-85 multi-year contract for the T700 engine would result in cost savings of $22.5 million. This represents a 5-percent savings on a $430.7 million multi-year contract versus $453.2 for three single-year contracts to procure 1,036 engines. The FY 1986-88 multi-year proposal called for procurement of

1,368 T700 engines at $642 million. Savings were estimated at $71.1 million, a 10 percent savings over three annual contracts estimated at $713.1 million.

The Army believed the T700 met the criteria for selection as an MYP program. The GAO concurred with the Army assessment. The requirement for the T700 series engine has always been stable. One thousand forty-four systems that use this engine--699 UH-60A Black Hawk, 30 EH-60A Quick Fix, and 315 AH-64 Apache aircraft--had been procured at the time of the FY 1986-88 MYP request. In addition, the procurement objectives for the UH-60A Black Hawk, EH-60A Quick Fix and AH-64 Apache have until recently been increasing. Funding for the three aircraft programs has until recently been stable. They are three of the Army's high priority programs. Procurement of the UH-60 and EH-60 airframes has been through multi-year contracts since FY 1982. The configuration of the T700 series engines was considered stable at the time of the FY 1983-85 MYP proposal. The contractors had achieved all technical and reliability goals. Two single-year fixed-price incentive (FPI) contracts and four single-year firm-fixed-price (FFP) contacts preceded the multi-year buys.

Confidence in the Army's estimate of cost savings due to MYP was high because data from the six fixed-price contracts, and data collected during visits to the contractors' sites were used to develop the estimate. A contractor analysis of expected cost savings from the second MYP contract is shown on Figure C-8. These estimates were compiled by the engine contractor in September 1985. Note that the unit price was anticipated to be 11 percent lower in the second MYP contract than in the first.

CCDR data for the T700 engine program were used to estimate cost of engines during the multi-year period if an annual contracting strategy had been pursued. Figure C-9 shows actual recurring unit prices for the T700 by lot. Engines in lots 4, 5, and 6 were bought with annual contracts; lots 7, 8, and 9 engines were bought under the first MYP
contract; and lot 10 is the first year of the second MYP buy. These unit prices are contrasted with an estimate of unit prices by lot had annual procurement been continued.

We estimate that during the first four years of multi-year procurement, the average might differ as much as 20 percent ($.54 million per unit) if annual buys had continued versus the $.45 per unit experienced under the multi-year contracts to date. Total lot costs under MYP are $436.4 million. We estimate they could have been as high as $524.3 million if annual contracts had been used.

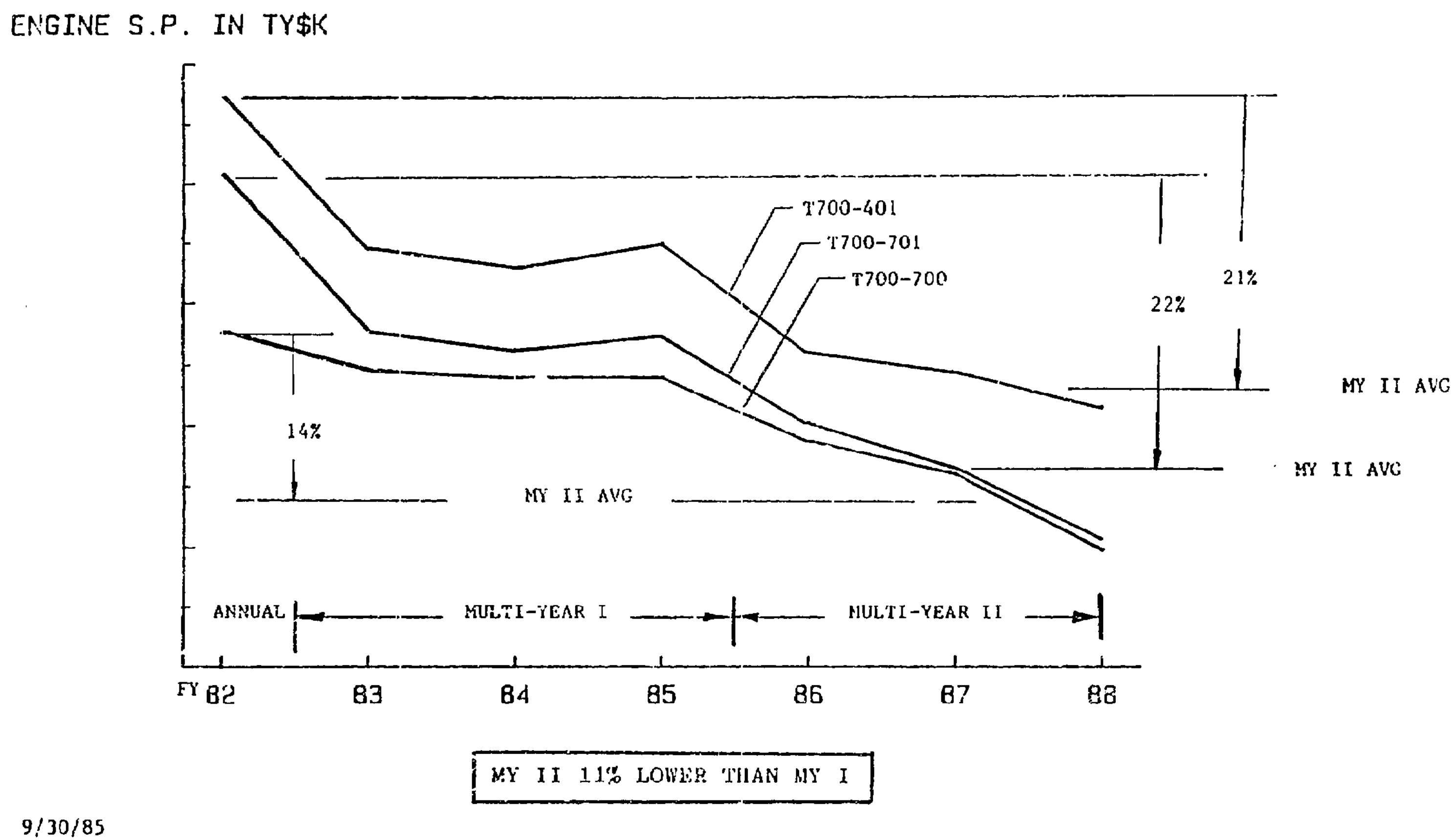
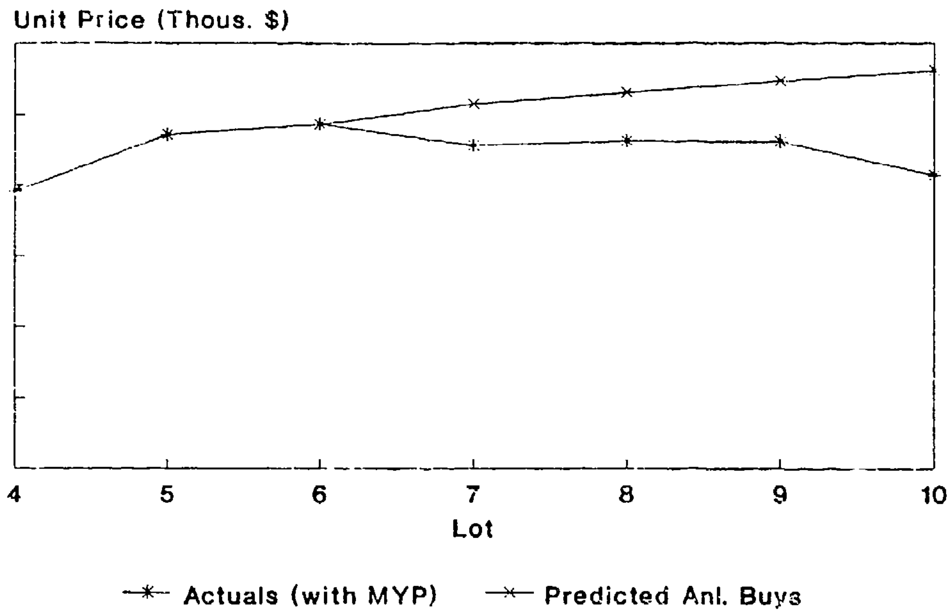


Figure C-8. T700 Sell Prices



Source: T700 CCDRs.

Figure C-9. T700 Engine MYP Analysis

The CCDR data strongly support the Army's estimated savings due to use of an MYP contracting strategy. It is unlikely that the actual savings would be as large as the 20 percent presented here. The estimate of average recurring unit prices for a series of annual contracts is based on the actual annual lots 4, 5, and 6. During that period the contractor had difficulty containing costs. It is unlikely that the contractor's cost performance would not have improved over time. However, it is interesting to note that the first lot to experience a decrease in unit price is lot 7, the first lot of the first MYP contract.

REFERENCES

[C-1] Gogerty, C. D., et al. *Tactical Munitions Acquisition Outcomes and Lessons Learned, Vol. 1: Summary Report.* Institute for Defense Analyses, IDA Paper P-2173, forthcoming.

[C-2] U.S. General Accounting Office. "An Assessment of the Army's Multiple Launch Rocket System Multi-year Contract." Report to the Chairman, Subcommittee on Defense, Committee on Appropriations, House of Representatives, 28 October 1985.

[C-3] U.S. General Accounting Office. "Procurement, Assessment of DoD's Current Multi-year Candidates." Briefing Report to the Chairman, Subcommittee on Defense, Committee on Appropriations, U.S. Senate, September 1986.

[C-4] U.S. General Accounting Office. "DoD Procurement, Multi-year and Annual Contract Costs." Report to the Chairman, Committee on Armed Services, House of Representatives, October 1987.

[C-5] U.S. General Accounting Office. "An Assessment of the Air Forces' F-16 Aircraft Multi-year Contract." Report to the Chairman, Subcommittee on Defense, Committee on Appropriations, House of Representatives, February 1986.

[C-6] U.S. General Accounting Office. "Procurement, Analysis of DoD's Fiscal Year 1986 Multi-year Candidates." Report to the Chairman, Subcommittee on Defense, Committee on Appropriations, U.S. Senate, November 1985.

Appendix D

COMPETITION CASE STUDIES

APPENDIX D
COMPETITION CASE STUDIES

A. AIRCRAFT ENGINE COMPETITION

In estimating the effect of competition on both the Air Force's F100/F110 and the Navy's F404 programs, the primary analytical tool used is the price-improvement or learning curve. The measure of effectiveness used is the decrease in engine procurement prices that can be reasonably attributed to the introduction of competition. The emphasis in the analysis of the F100/F110 fighter engine competition is the effect on Pratt & Whitney F100 unit prices of the introduction of the General Electric F110 as an alternative engine for powering F-15 and F-16 aircraft. In the case of the F404 competition, where functionally identical engines were bought from both General Electric and Pratt & Whitney to power the F/A-18 fighter, a more complete cost-benefit analysis is performed.

1. F100/F110 Alternative Fighter Engine

The progression of Air Force decisions that led to the fighter engine competition did not consciously start with the idea of second-sourcing F-15 and F-16 propulsion business. Initially, the Air Force wanted a stand-by alternative to the F100, its only engine to power its front-line fighters. An alternative fighter engine would provide insurance against the failure of Pratt & Whitney's efforts to solve the F100's numerous reliability, maintainability and operability problems, as well as against other eventualities that could threaten the viability of the F100. Implicitly, the Air Force wanted to gain leverage on Pratt & Whitney, whose response to F100 problems was judged unsatisfactory by many [D-1].

General Electric's F101 engine, which was developed for the B-1 bomber, formed the basis for the alternative engine. A modification of that engine, the F110, was developed for application to F-15 and F-16 aircraft. The primary objective of starting the competition was *not* the lowering of unit production prices. Instead, the emphasis was on obtaining more reliable, maintainable, and operable engines. The F110 also had the advantage of higher thrust [D-1].

We limited our analysis to the effect of the fighter engine competition on F100 prices. As the F110 and F100 engines are functionally different, and there is no pre-competition experience for the F110, no comparisons are made between F100 and F110 prices. Complicating analysis further were constant changes in the F100's configuration. Hundreds of millions of dollars of Component Improvement Program (CIP) funds were spent on developing fixes to address service-revealed problems. Engineering changes were in turn incorporated into F100 production engines. The introduction of competition coincided with a major model change from the F100-P-100/200 to the F100-P-220. Because of configuration changes, the F100's learning curve contains discontinuities.

In constructing a learning curve for the F100 production, lot unit prices for Air Force-procured installation engines are regressed against the cumulative quantity of all F100 engines, including those produced for foreign military sales (FMS). These data were obtained directly from Pratt & Whitney. In years where both F100-P-100 (original F-15 application) and F100-P-200 (F-16 application) engines were bought, prices for the F100-P-100 are used. We normalized prices to constant 1987 levels using propulsion industry indices developed the by the Naval Air Systems Command (NAVAIR). A nonlinear regression routine is used to simultaneously estimate lot midpoints and learning curve parameters. Indicator variables (1, 0) are used to account for shifts in the learning curve due to competition and engine configuration changes. The resulting curves are as follows:

F100 Unit Cost, 87K\$ = 7950 $Q^{-.15}$, learning curve slope = 90%

FY 80-81 Model Change = + 441, significantly different from 0 at the .05 level

–100 to –220 Model Change and Start of Competition = + 177, not significantly different from 0 at the .05 level, $R^2 = .94$,

Figure D-1 presents the price-improvement curve for the F100 program.

A large increase in unit price occurred with the fiscal year 1981 engine buy. The shift upwards in the unit learning curve at this point is estimated to be \$441,000 (significantly different from zero at the .05 level). The reason for this large upward shift in the learning curve is not entirely clear. One hypothesis is that fiscal year 1981 marked a large change in engine configuration. This hypothesis is supported by a relatively large decrease in the unscheduled engine removal (UER) rate for the fiscal year 1981 engines, where UER performance is considered an important indicator of engine reliability and durability.

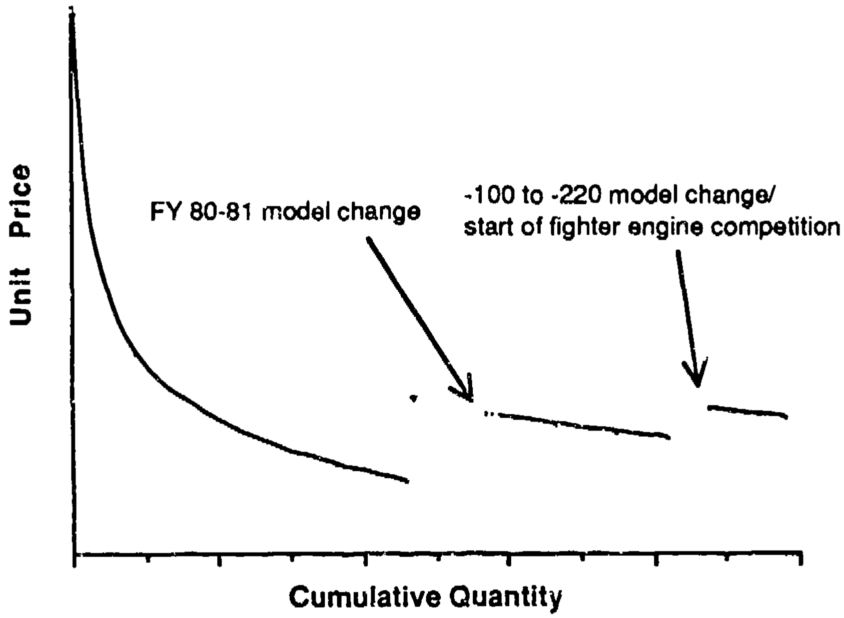


Figure D-1. F100 Learning Curve Analysis

As previously mentioned, the first year of competition, fiscal year 1985, corresponded with a major change in F100 hardware. This change was great enough to warrant a change in engine series designation from -100/200 to -220. The fiscal year 1985 buy causes a slight upward shift in the learning curve, estimated at $177,000. This shift is not significantly different from zero at the .05 level. As the effects of competition are confounded by the model change, the results are open to interpretation. A reasonable interpretation is that the model change, which would have proven costly under the old regime (as evidenced by the large upward shift of the learning curve for the fiscal year 1981 buy) did not cause a statistically significant upward shift in the learning curve.[1] Given this interpretation, the introduction of competition into the F100 program has had a favorable effect on F100 unit prices.

It must be kept in mind that a reduction in production prices was not the primary goal of the fighter engine competition. The central motivation was the improvement of engine reliability, durability, and operability. Measuring the effects of competition on these aspects of engine performance is not attempted. Such an analysis would require a large

1 In discussions with Air Force representatives at the propulsion system program office at Wright Patterson Air Force Base, the -100/200 to -220 model change was said to represent a substantial change relative to earlier F100 configuration changes.

data collection effort. In addition, field experience with the engines procured under competition is limited.

2. F404 Engine

In the second-sourcing of the Navy's F404 engine, the objective of the competition was more clearly to lower procurement prices. The F404 engine did not suffer from a high level of service problems in the field, as did the F100. In establishing Pratt & Whitney as an alternative source of F404 engines, a series of "education buys" was non-competitively awarded.[2] The first buy of Pratt & Whitney engines was in fiscal year 1985, while the first buy actually competed was in fiscal year 1988. The effects of competition are examined from the initial establishment of the second source as opposed to the actual initiation of competition. The hypothesis is that the simple establishment of a second source should create downward pressure on lot prices.

Again the production price-improvement curve is our main tool of analysis. Data for both General Electric and Pratt & Whitney contract prices were obtained from the Navy. Additional F404 data supplied directly from Pratt & Whitney proved consistent with the Navy data. As in our F100 analysis, lot prices are normalized into constant 1987 dollars and quantities encompass all production, including FMS. Separate learning curves are estimated for General Electric and Pratt & Whitney experience. In order to test for the effect of second-source establishment on General Electric prices, a 0, 1 indicator variable is used to estimate a rotation parameter for the General Electric learning curve. The resulting curves are as follows:

$$\text{G.E. Unit Price, 87K\$} = 3886\ Q^{-.105},\quad \text{slope} = 93\%,$$

$$\text{After Second Source} = 3886\ Q^{-.135},\quad \text{slope} = 91\%,$$

$$R^2 = .98$$

$$\text{P\&W Unit Price 87K\$} = 4026\ Q^{-.19},\quad \text{slope} = 89\%,$$

$$R^2 = .95,$$

The difference between the pre- and post-second-source learning curves is estimated by the rotation parameter, which is statistically different from zero at a .05 level of significance. The slope of the first source learning curve declined after competition from 93 percent to 91 percent. The slope of the second source learning curve was even lower at

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2 This differs from the case of the F110, where all production engines were bought on a competitive basis.

89 percent. Figure D-2 presents the learning curves estimated for both Pratt & Whitney and General Electric experience.

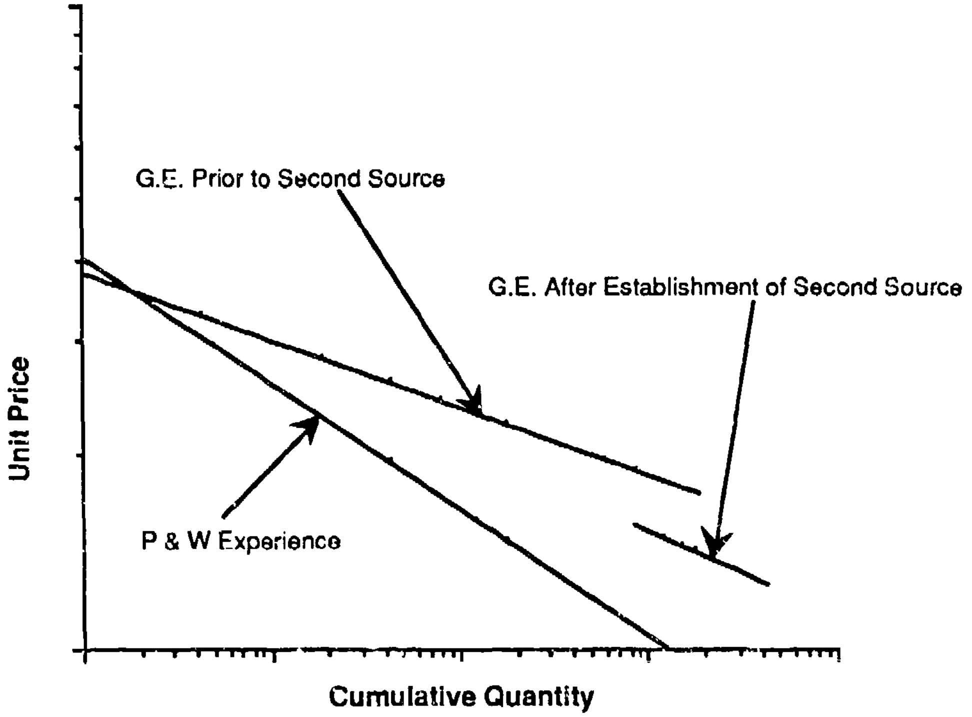

Figure D-2. F404 Learning Curve Analysis

A possible confounding influence was revealed in discussions with NAVAIR representatives. Between fiscal years 1983 and 1984 the unit prices the Navy paid for their turbine engines decreased. The decreases were said to be a result of lower prices for advanced materials. The decreases in materials prices, however, are not reflected in the price indices we use, or in the behavior of F100 prices over the same time period. We attempted to test the materials price hypothesis by including an additional 1, 0 indicator variable designating all procurement lots prior to fiscal year 1984. The indicator variable is multiplied by an additive shift parameter whose value is expected to be positive. As there is only a single lot associated with the materials price decrease and not with second sourcing, it is difficult to distangle the two effects. Indeed, when both parameters are estimated, neither is significantly different from zero at the .05 level. They are however significantly different from zero at the less stringent .10 level. The resulting equation is as follows.

$$\text{G.E. Unit Price 87K\$} = 3615\ Q^{-.107},\ \text{slope} = 93\%,$$

$$\text{After Second Source} = 3615\ Q^{-.125},\ \text{slope} = 92\%,$$

$$\text{Add \$211,000 for lots procured before fiscal year 1984},$$

$$R^2 = .98$$

As expected, the rotation parameter is smaller when an attempt is made to account for changes in materials prices. When we look at the costs and benefits of the F404 second-sourcing, estimates of price savings generated by the equations with and without the materials-price shift parameter will be included in order to test the sensitivity of the results.

Benefits are quantified by comparing price estimates generated by the pre-second-source learning curve and G.E./P&W actuals for lots already definitized and estimates generated by the Pratt &Whitney and post-second-source General Electric learning curves for future lots. For these future lots, we assume even splits between G.E. and P&W with 200-engine lots through fiscal year 1992. Non-recurring costs were supplied by the Navy and include both second-source qualification costs as well as tooling costs. These costs are also normalized to constant 1987 dollars. A discount rate of 10% is used in calculating costs and benefits. Figure D-3 shows estimated cumulative costs and benefits (savings) for the F404 competition where savings are estimated both with and without accounting for decreases in materials costs (baseline model and modified model). Given the two models and the above assumptions, net savings, or benefits, of the F404 competition range from approximately $125 million to $300 million in constant 1987 dollars.

3. Conclusions

In judging the success of the two engine competitions, the use of decreases in unit prices as a positive criterion is most appropriate for the case of the F404. Given experience thus far, it appears the F404 competition has been a success. By concentrating on unit price effects we tend to ignore the greatest potential benefits of the F100/F110 competition--the decline in overall ownership costs and increased F-15 and F-16 operational effectiveness. Unfortunately, these are beyond the scope of the study. However, it appears that competition and a major model change occurred at the same time on the F100 without substantial cost to the government.

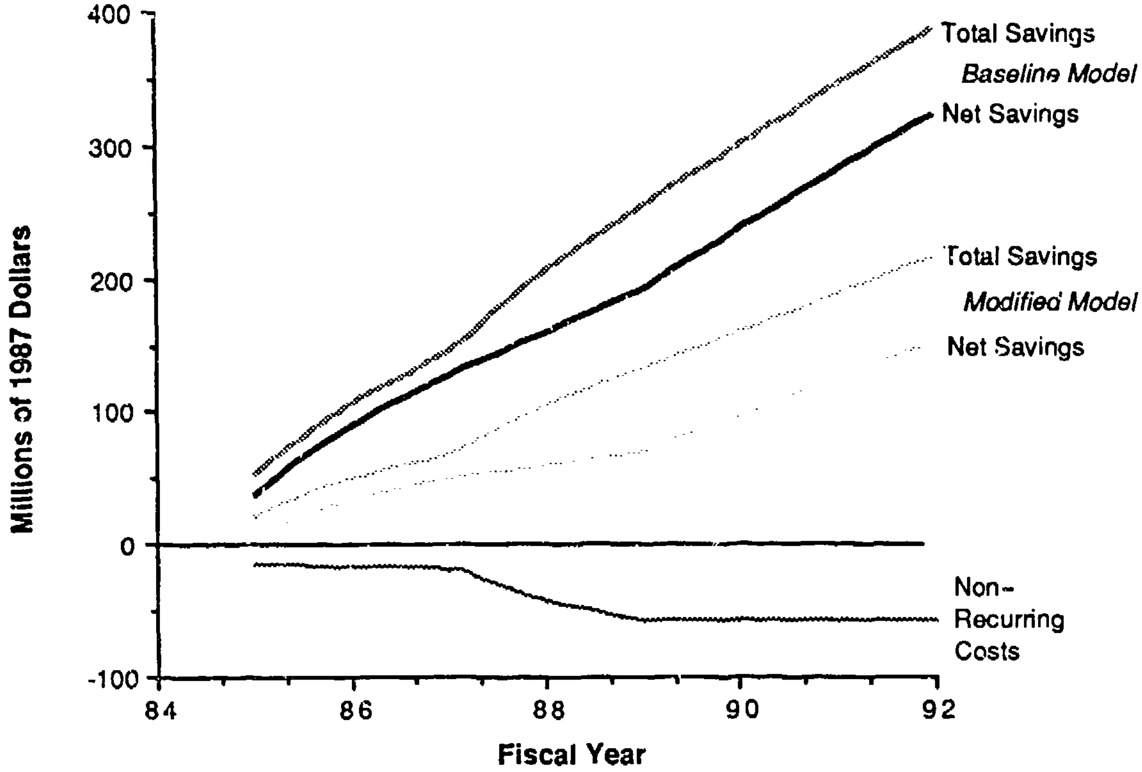

Figure D-3. F404 Competition Cost-Benefit Analysis

B. HARM MISSILE

1. Program Description

The High-Speed Antiradiation Missile (HARM) AGM-88A is an air-to-ground missile for use against land- and sea-based radar emitters associated with enemy air defenses. HARM was developed at the Naval Weapons Center, China Lake, California, as a joint Navy-Air Force program. The development contract was awarded in May 1974 to Texas Instruments (TI). Under the fiscal 1981 initial production contract, TI was responsible for weapon system integration (except for the government-furnished warhead).

2. Competition Implementation

Texas Instruments was the incumbent contractor. Three other contractors--Ford, Raytheon, and Bendix--took the TI hardware and design and proposed how they would manufacture that design. The three competing contractors made a total investment of $26 million. At the time, Texas Instruments had no real competition in anti-radiation technology, and the HARM involved a high technology requirement. Congressional direction to compete in 1979 followed by Navy Secretariat direction in 1981 intensified the threat to TI. According to [D-2], the program manager had only a minimal role in the competition. In December 1982 the Navy threatened cancellation of the program unless TI substantially reduced program costs. TI agreed to several producibility engineering proposals that reduced production costs by around 3 percent. TI also agreed to provide firm, not-to-exceed price quotations for two years into the future [D-3]. The government had possession of the Level III Technical Data Package, so technology transfer was at least feasible. The potential competing contractors invested $26 million in startup costs [D-2]. There was also a $5 million government investment in qualifying the three contractors [D-4].

Competition was never implemented, because TI dropped its price substantially, from $937.5 thousand per unit in 1981 to $514.4 thousand per unit in 1982 and $313.8 thousand per unit in 1983. The DSARC III decision memorandum in 1983 directed sole-source procurement, primarily because the council doubted that the estimated $80 million cost of developing and qualifying a second source could be recouped given TI's pricing structure.

3. Program Cost Summary

Unit cost to the government declined considerably from $937.5 thousand in 1981 to $121.8 thousand in 1987 (Table D-1). In addition, quantitative program outcomes were generally favorable, relative to both competitive and non-competitive tactical munitions. HARM had a very smooth development in terms of schedule, but it had high development cost growth. The HARM program had lower total program cost growth than average, despite the fact that it bought only 1.05 times the planned quantity (Table D-2).

Table D-1 HARM Cost by Fiscal Year

FY	Quantity	Total Cost (1975 $) (Millions)	Average Unit Cost (Millions)
81	80	75	.9375
82	236	121.4	.5144
83	283	88.8	.3138
84	635	193.2	.3042
85	1684	299.2	.1777
86	2150	298.2	.1387
87	2398	292.1	.1218

Source: Reference [D-4].

Table D-2. HARM Outcome Versus Competitive and Non-Competitive Tactical Munitions Programs

	HARM	Competitive (Average)	Non-Competitive (Average)
Cost Growth			
Total Program	1.47	1.78	2.16 (16)
Production	1.39	1.82	2.46 (16)
Development	2.03	1.88	1.42
Production Quantity Growth	1.05	1.74	0.78 (16)
Stretch	1.53	1.76	3.15[a] (15)
Schedule Growth			
Development	1.05	1.89	1.42
Production	1.61	2.19	1.60 (15)
N	1	11	17

[a]Condor (stretch = 56) omitted from calculations.

4. Analysis of Competition Goal Achievement

There was a considerable price drop between FY 1981 and FY 1982 and between FY 1982 and FY 1983. It is unclear whether this drop would have occurred without the threat of competition. It was not possible to do a learning curve analysis of the competition threat, because there was only one pure sole-source year before the competition threat.

The program office also cites the restructuring of the program for a faster buyout as having a favorable effect on price. In addition, the office uses competition at the vendor/component level and component breakout [D-3].

C. SPARROW AIM-7F MISSILE

1. Program Description

The Sparrow AIM-7F was developed by Raytheon. It is part of a family of six semi-active, radar-guided missiles, all of which were Raytheon-developed. These include the AIM-7C, AIM-7D, AIM-7E, AIM-7E2, and the later version AIM/RIM-7M [D-5]. The AIM-7F had a solid-state guidance system, a "snap start" capability, and a new motor and warhead.

2. Competition Implementation

The Navy decided on dual-source production of the AIM-7F in early 1971, toward the end of engineering development. The motivations for the competition included increasing system performance and reliability, greater contractor responsiveness, reducing price, and increasing the mobilization base. The Navy was concerned that the performance of the missile was not what it could be for such a mature program, and the Navy believed that a second source would help. Technology transfer was accomplished by the Naval Weapons Center at China Lake, because Raytheon's technical data package was believed to be inadequate.

General Dynamics, Pomona Division, won contracts in early FY 1973 for program planning for future second sourcing and for 15 qualification units. Competition was planned for FY 1975, but had to be delayed. GD was not qualified until June 1976 and was awarded a pilot production contract for 70 units. However, by late FY 1976, GD was still not able to bid competitively, so GD received a directed buy.

Annual competitions were held from 1977 through 1980. Raytheon won the larger share of the buys three out of four times.

3. Program Cost Summary

Table D-3 shows the key variables in our study for the AIM-7F. The program ran into serious problems in development--the development schedule was almost four times as long as planned and development cost was over four times the plan.

Table D-3. AIM-7F Outcomes Versus Competitive and Non-Competitive Tactical Munitions Programs

	AIM-7F	Competitive (Average)	Non-Competitive (Average)
Cost Growth			
Total Program	1.74	1.78	2.16 (16)
Production	1.58	1.82	2.46 (16)
Development	4.25	1.88	1.42
Production Quantity Growth	1.66	1.74	0.78 (16)
Stretch	1.16	1.76	3.15[a] (15)
Schedule Growth			
Development	3.90	1.89	1.42
Production	1.93	2.19	1.60 (15)

[a]Condor (stretch = 56) omitted from calculations.

Despite this poor showing in development, production outcomes were very good. As with other competitive programs in the study, the AIM-7F program acquired higher quantity than planned. The stretch index was low, a key factor in program success. Production cost growth was only 1.58, substantially lower than the average for either competitive or non-competitive programs. Overall, total program cost growth (1.74) was typical of competitive tactical munitions programs.

4. Analysis of Competition Goal Achievement

Several analyses have been done on the outcome of the AIM-7F competition. We looked at recurring flyaway costs from FY 1972 through FY 1976 for the first source. The estimated learning curve was:

$$\text{Cost} = 3.88 * Q^{-.372501} \qquad (R^2 = .94, \text{ slope} = 77.24\%)$$

This learning curve was used to estimate what the cost of the entire buy of 9,207 missiles would have been under sole-source conditions. The estimate was $1,193.1 million, versus an actual cost of $1,346.6, in 1985 dollars. Thus, we indicate a loss from competition of approximately 13 percent.

A Rand study by Birkler and Large [D-6] examined the material cost and factory labor hours for Raytheon and General Dynamics. They found lower material costs after competition, but higher factory hours. They also found that engineering support hours and factory support hours varied little with competition.

The Naval Center for Cost Analysis [D-5] estimates the startup cost of the competition at $82.6 million in FY 1985 dollars, or about 6 percent of total procurement cost. This startup cost includes costs for special tooling and test equipment, for qualification of General Dynamics, and for extra funds provided to Raytheon to improve its technical data package. It does not include government costs such as the assistance provided by China Lake.

The Naval Center for Cost Analysis examined historical Contractor Cost Data Reports (CCDRs). Results were different depending on when competition was assumed to begin. There is some justification for assuming that competition began at Lot 3 (FY 1975), as planned. Raytheon was apparently unaware of the extent of General Dynamics' difficulties in becoming qualified when it submitted its Lot 3 bid. However, competition actually began at Lot 5 (FY 1977 buy).

The Naval Center for Cost Analysis found a net price savings of between $57 million and $101.7 million (FY 1985 dollars) when competition was assumed to begin at Lot 3, and a loss of between $103.4 million and $290.2 million when competition was assumed to begin at Lot 5. These translate to a savings of 4% to 7% if Lot 3 competition is assumed, or a loss of 8% to 28% if Lot 5 competition is assumed.

Beltramo, Collins, and Olshan [D-7] evaluated the Naval Center's work and used some additional data. They noted that, while Raytheon staff was unaware that Lot 3 would be a directed buy, the staff knew that Lot 4 would be. They found a similar pattern. when Lot 5 is considered the start of competition, there is a net loss, and when Lot 3 is considered the start, there is a net saving. However, they evaluated the overall costs of competition, including the upfront investment and discounted savings, and found a loss in both cases.

With respect to non-cost goals, Berg et al. [D-8] report that the government believed that they regained control of the program as a result of competition. They believed that the contractors did try to improve productive efficiency once the initial technical problems were dealt with.

5. Findings

Evidence suggests that the Sparrow AIM-7F competition increased factory labor hours and engineering hours [D-5, D-6]. Thus, any savings from competition has to come from somewhere else--materials costs, overhead, or profits.

The evidence on price savings from competition is generally negative. If we assume that competition began when it was planned, in FY 1975, savings on the order of 4.1% to 7.1% occurred. However, if we track from the actual start of competition in FY 1977, competition resulted in a loss on the order of 8.5% to 27.9% [D-5]. According to [D-7], if we include the upfront investment in competition and use an appropriate level of discounting, then there is a loss in both cases. Our own analysis, assuming that competition began with Lot 5, found a net loss of 13 percent, not including the upfront investment.

The development cost growth experience of the AIM-7F was extremely poor. By contrast, production outcomes were very good. As with several other competitive programs, the AIM-7F program acquired more quantity than planned over a longer time than planned. Thus, it is not clear whether the favorable production cost growth outcome was due to the fact that the program was not stretched or due to the competition.

The government apparently was pleased with the non-cost aspects of the competition (e.g., regaining control of the program and introducing more efficient production methods).

D. MAVERICK IIR MISSILE

1. Program Description

a. Background

The AGM-65D is a rocket-propelled, air-to-surface, precision-guided missile that develops tracking signals from the naturally occurring thermal energy of the target. It is designed to destroy small, hard tactical targets during day or night even under limited adverse weather conditions in the counter-air, interdiction, and close air support operations of the tactical air force. The AGM-65D can be used by the A-7, A-10, F-4, F-15E, F-16, and F-111 aircraft.

The IIR Maverick development estimate assumed start of engineering development in April 1977. However, Congress denied funding, and engineering development was initiated in October 1978. IOT&E results reported as part of the September 1982 review cycle indicated that operational effectiveness was satisfactory, but that operational suitability was deficient. Test data from the next OSD review held in April 1983 indicated improved reliability. IOC was over four years late (planned June 1981 vs. actual February 1986).

b. Acquisition Strategy

A prototype for the missile's seeker was developed. CPIF contracts were done during early development and design-to-cost was practiced during FSD. The program planned for MYP, but it was later deleted from the plan. Production contracts were fixed-price incentive for FYs 1982 and 1983 and firm-fixed-price thereafter.

2. Competition Implementation

Although dual-sourcing of the whole system in FSD was not implemented, there was subsystem competition.

Raytheon received a second-source development contract in 1983 for $76.2 million to build qualification missiles. A separate time and materials contract was given to Hughes to support bringing on a second source for Maverick, with total funding of $5.641 million in FY 1983. Hughes also supported the second source under the weapon system support contract F33657-86-C-0130, P0011.

In production, there was a leader-follower competition, with Hughes as the leader and Raytheon as the follower. Hughes produced sole source from FY 1982-1986. (Raytheon produced 800 missiles in FY 1986 as an option on its development contract.) Hughes raised its unit price in FY 1986, its last sole-source year. The first head-to-head competition, in FY 1987, was won by Hughes, with 65.7 percent of the buy. In FY 1988, Raytheon won 63.7 percent of the buy. In FY 1989, Hughes won 59 percent of the buy. Thus, the two contractors have alternated in three competitive years.

3. Analysis of Competition Goal Achievement

Cost growth in the Maverick program was low in development and moderate in production (Table D-4). Figure D-4 shows Maverick unit prices and quantities by fiscal year.

Table D-4. Maverick Outcomes Versus Competitive and Non-Competitive Tactical Munitions Programs

	Maverick	Competitive (Average)	Non-Competitive (Average)
Cost Growth			
Total Program	1.53	1.78	2.16 (16)
Production	1.58	1.82	2.46 (16)
Development	1.07	1.88	1.42
Production Quantity Growth	1.95	1.74	0.78 (16)
Stretch	1.10	1.76	3.15[a] (15)
Schedule Growth			
Development	1.98	1.89	1.42
Production	2.14	2.19	1.60 (15)
N	1	11	17

[a]Condor (stretch = 56) omitted from calculations.

The sole-source price-improvement curve (FY 1982-86) for Hughes was:

$$\text{Unit cost} = 1710.8^{*}\ \text{CUMQ}^{-0.407}$$

$R^2 = .92$, Sole-source slope = 75.4%

We used this curve to project what sole-source costs would be, then compared these costs with actual costs of the competition (Figure D-5). The net difference line includes the $81.841 million in Raytheon development costs and Hughes support costs.

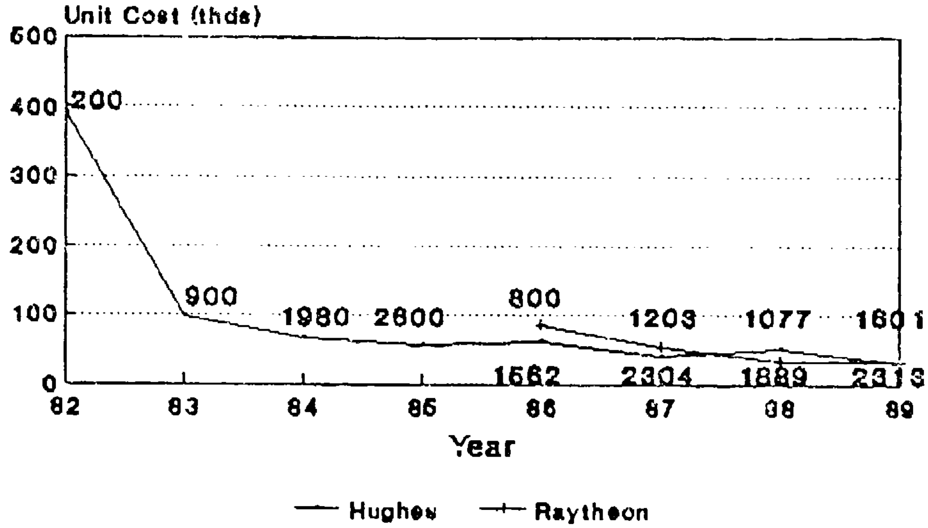

Figure D-4. Maverick Costs and Quantities

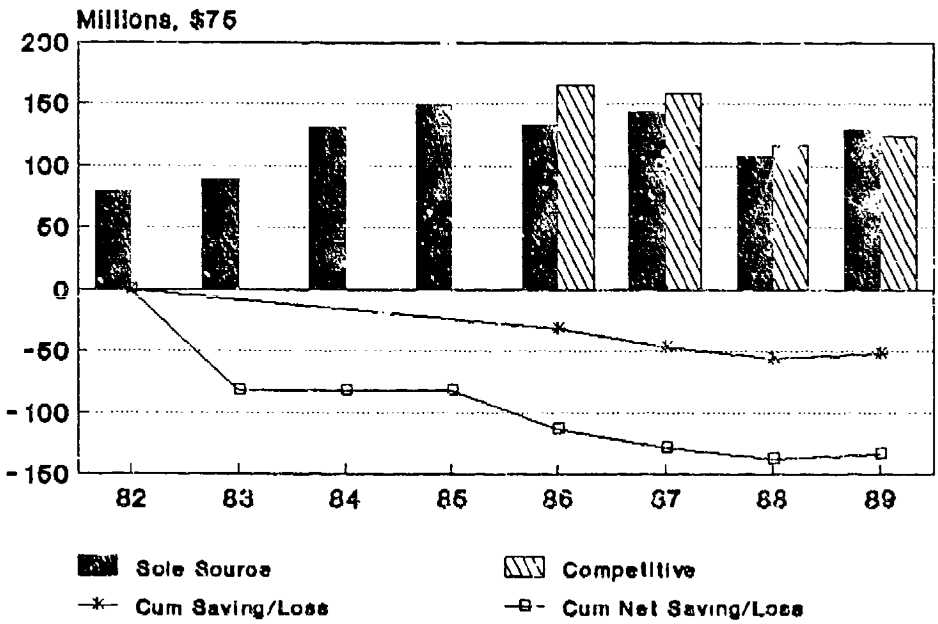

Figure D-5. Maverick Cost-Benefit Comparison

If one looks at procurement costs, FY 1989 is the first year in which the government paid less under competition than it would have under sole source. Cumulatively, the government still has losses from prior years to overcome. On a net basis (including startup costs), the government's losses are greater. Since procurement plans stretch as far as FY 1997, however, it is possible that the government may see net savings from the competition.

4. Findings

With respect to cost growth, the Maverick program has performed well. With respect to competition, the results are not yet clear. It appears that there is potential for the government to achieve savings, but they have not yet occurred.

E. TOMAHAWK MISSILE

1. Program Description

a. Background

The Tomahawk cruise missile has three variants--Land Attack Missile/Conventional, Anti-Ship Missile, and Land Attack Missile/Nuclear. The Joint Cruise Missile Program Office (JCMPO) was established in 1977 to develop the Air-Launched Crusie Missile (ALCM) and Tomahawk for the Air Force and Navy with maximum commonality. The Navy was designated as lead service. Approval for full production of all three variants was granted in September 1987.

b. Acquisition Strategy

Two prime contractors were awarded CPFF contracts in January 1974, leading to a competitive fly-off. The competitive prototype was primarily for proof of concept rather than operational suitability. As will be discussed, competition was a part of the acquisition strategy. The program also had a formal design-to-cost goal. However, DTC was not aggressively managed in the program.

There were award fees on major development contracts. However, the program office does not view the results of these favorably. Award fees, initially regarded as a useful "carrot", were later regarded as too difficult to administer, taking time away from solving technical problems, and with the settlements coming too late to make a difference.

2. Competition Implementation

Competition came about as a result of government unhappiness with the responsiveness of the major contractors, including ability to produce, management of subcontractors, technical problems, and price. The program office was concerned about too many crashes. At the time, competition was not a common acquisition strategy and had to be justified up the line. The program was experiencing serious manufacturing and quality problems in FSD [D-2].

McDonnell Douglas was already building the guidance system and indicated that it would be possible to build the airframe also, while General Dynamics, the airframe builder, could get guidance data and also build the whole missile. Both contractors invested in their own qualification, and required acceptance of contingent liability by the government. General Dynamics had more to lose from competition--it was providing about 90 percent of the value added. In contrast, McDonnell was putting together a guidance set essentially provided by Litton.

The government took steps to minimize its upfront investment in competition. The government added an investment incentive clause to contracts, which allowed the contractors to recover costs of tooling and test equipment amortized over the life of the program. (Thus, while the government ultimately paid more for such equipment, its upfront investment was minimized.) The Navy refused to put up money to fund technology transfer. Instead, contractors were allowed to bill back 1/1200 of the cost for each of the first 1,500 missiles. The program office estimates that $17.5 million was invested by the companies.

There were four joint-production years (FYs 1981-84). In FY 1984, there was a directed buy from each company to ensure that both companies were ready to build the whole missile. Four head-to-head competitions have been held since then. General Dynamics won 70 percent of the FY 1985 buy and won again in FY 1986. McDonnell won in 1987, and General Dynamics won in 1988. General Dynamics was able to point to its 1987 loss to keep wage increases lower in strike negotiations.

3. Program Cost Summary

In our database, program outcomes for Tomahawk look poor in development and good in production. Outcomes are shown in Table D-5.

Table D-5. Tomahawk Outcomes Versus All Strategic Missiles

	Tomahawk	All Strategic Missiles
Development Cost Growth	1.66	1.15
Development Schedule Growth	1.48	1.34
Development Quantity Growth	0.91	0.87
Production Cost Growth	1.5	1.58
Production Schedule Growth	1.46	1.39
Production Quantity Growth	3.69	1.47
Total Program Cost Growth	1.57	1.37

From this summary, the problems in development are clear. Development cost and schedule growth were above average (1.15 and 1.34, respectively) for strategic missiles. However, if production continues according to plan, cost growth in production will be slightly less than average (1.58) for strategic missiles. The program also exhibits a large increase in planned quantity, which makes the stretch index very low.

4. Goal Achievement

Several evaluations have been done on the impact of competition on the Tomahawk program, although, to our knowledge, none have yet been published:

- The program office, on the basis of a consolidated competitive learning curve, found savings of $2.9 billion over the period 1986-88. They use all-up-rounds normalized for government-furnished equipment (GFE). By 1989, all GFE is expected to be eliminated except for fuel and the warhead.
- A PA&E study (which we did not review) found that competition saved $91 million.
- A Rand study in process is having trouble finding any evidence of savings. Any savings calculations were found to be sensitive to the assumed slope of the sole-source learning curve, with one or two percentage points making the difference between competition yielding savings or costing the government money. They caution that the price-improvement curve cannot be predicted with that degree of precision.
- The Naval Center for Cost Analysis did an independent evaluation that includes the FY 1989 contract prices and quantities and found savings of approximately 15 percent.
- These savings were realized even after several items of previously GFE and government-furnished engineering support were incorporated into the prime competitors' contracts.

5. Findings

Our analysis yields the following findings:

- Members of the program office believe that competition in the Tomahawk program is a major success. They see large dollar savings and the resolution of technical problems. The program office says that competition seems to be successful in missile programs where there is teaming in development and a high production rate. However, they see danger in mixing competitive programs and sole-source programs in the same plant. They also believe that MYP is incompatible with competition, although they would consider a multi-year buyout at the end of the program. However, for the present they believe that competition is working very well.
- Other evaluators of the Tomahawk disagree. In general, they find savings, but one cautions that findings are very sensitive to assumptions about sole-source behavior.
- The program office sees understanding how the private sector works as a key to the success of competition.
- Our evaluation shows lower savings than the program office estimates.

F. HELLFIRE MISSILE

This case study was developed from information in Miller and Palmer [D-4].

1. Program Description

Hellfire is an air-to-ground missile system that uses semiactive laser terminal homing guidance. The AGM-114A version is used on the Army's AH-64 Apache attack helicopter. The Marine modified AH-1 helicopters use the AGM-114B version of the missile.

2. Acquisition Strategy

The Hellfire program began advanced development in 1972 with competition between Rockwell International and Hughes Aircraft. Rockwell won the development contract and entered full scale development (FSD) in 1976.

The major initiatives applied, besides competition, were competitive prototyping and design-to-cost. The Office of the Secretary of Defense (OSD) delegated authority to the Army for the Milestone III review and for approval of full-rate production.

The major initiatives applied, besides competition, were competitive prototyping and design-to-cost. The Office of the Secretary of Defense (OSD) delegated authority to the Army for the Milestone III review and for approval of full-rate production.

3. Competition Implementation

The potential for competition occurred in 1977 when Martin Marietta submitted an unsolicited proposal for a privately developed alternative seeker. A seeker competition was held between Rockwell and Martin Marietta, which Martin Marietta won. Thus, initial production of missile buses was done by Rockwell, and the seekers were produced by Martin Marietta.

In December 1982, the government called for a dual-source competitive strategy. Each contractor would produce a small number of all-up rounds for certification in 1983, and head-to-head competition was to begin in 1984.

The contractors agreed to a technology transfer plan that established the data and knowledge that would be shared, and they established special accounts to document these costs. The contractors were allowed to recover up to $5,000,000 of these costs over the first 6,000 missiles purchased from each contractor. If these costs were included in competitive proposals, they would obviously be included in the government's evaluation.

Bidding regulations required contractors to bid on a range of quantities from 1,125 through 4,500 missiles, and unit prices for any given quantity were required to fall on a single continuous logarithmic price line. Each of the two contractors was guaranteed a minimum of 40 percent in FY 1984 and 25 percent through the FY 1988 buy.

4. Findings

The overall program results for Hellfire are contained in Table D-6. Relative to other tactical munitions programs, Hellfire had a successful development, with low schedule growth and very low cost growth--only 1.09. The program had a stretch index of 1.2, which is very low even when compared with other competitive tactical munitions programs. The program ended up acquiring almost double the number of missiles planned. Production cost growth and total program cost growth were also low. Overall, by our measures of merit, the program looks successful.

Table D-6. Hellfire Outcomes Versus Competitive and Non-Competitive Tactical Munitions Programs

	Hellfire	Competitive (Average)	Non-Competitive (Average)
Cost Growth			
Total Program	1.40	1.78	2.16 (16)
Production	1.61	1.82	2.46 (16)
Development	1.09	1.88	1.42
Production Quantity Growth	1.98	1.74	0.78 (16)
Stretch	1.20	1.76	3.15[a] (15)
Schedule Growth			
Development	1.44	1.89	1.42
Production	2.38	2.19	1.60 (15)
N	1	11	17

[a]Condor (stretch = 56) omitted from calculations.

With respect to competition, the two contractors have alternated in winning the larger share of the buy in the four years for which data are available--1984, 1985, 1986, and 1988. The 1987 buy was skipped, because both contractors were behind in deliveries.

Miller and Palmer [D-4] found no evidence of a significant shift or rotation of the unit price improvement curve for recurring hardware costs. The slope of the unit recurring price curve, including both non-competition and competition years, is around 80 percent, neither unusually high nor unusually low. They concluded that the competition strategy was successful in the sense that there are now two prime contractors capable of providing fully assembled missiles, and that technology transfer and initial production facilitization costs appear to have been offset by the pressures of competition.

The alternating pattern of winning bids is interesting and is beginning to be seen in other programs. It appears that management strategy and not just cost plays an important role in determining contractor bids. In some sense, this alternating pattern may allow contractors to plan production better. However, it does not necessarily lead to dramatic cost savings for the government.

REFERENCES

[D-1] Drews, Robert W. *The Air Force and the Great Engine War.* National Defense University Press: Washington, D.C., 1987, pp. 93-97.

[D-2] Merrimack Associates. *A Synthesis of Case Studies in Production Competition.* Spring 1987.

[D-3] Kish, Ernest J. "Containing Weapon Program Costs in a Sole-Source Environment." *Program Manager*, vol. 15, no. 2 (March/April 1986).

[D-4] Miller, Bruce M., and Paul R. Palmer. *Tactical Munitions Acquisition Outcomes and Lessons Learned, Vol. 2: Case Studies.* Institute for Defense Analyses, Paper P-2173, forthcoming.

[D-5] Naval Center for Cost Analysis. *The Effect of Competition on Procurement Price* December 1987.

[D-6] Birkler, John L., and Joseph P. Large. *A Closer Look at Second-Source Procurement.* Rand Corporation, briefing, April 1987.

[D-7] Beltramo, Michael N., Richard B. Collins II, and Lisa Olshan. *The Effect of Competition on Procurement Cost: Analysis of Ten NCA Case Studies.* Science Applications International Corporation, February 1987.

[D-8] Berg, Robert M., et al. *Case Studies on the Use of Competition in the Sidewinder and Sparrow Missile Programs.* Center for Naval Analyses, CRM 87-126, July 1987.

Appendix E

DESIGN-TO-COST CASE STUDIES

APPENDIX E
DESIGN-TO-COST CASE STUDIES

A. F/A-18 AIRCRAFT

1. Program Description

The F/A-18 Hornet strike fighter is a single-seat, twin-engine, jet airplane that is designed to operate both from land bases and from aircraft carriers. The primary mission for the F/A-18 is fighter escort, and its secondary mission is fleet air defense.

The F/A-18 development plan was approved in December 1975, after the DSARC II review. The DSARC II Decision Memorandum of 22 December 1975 identified the major program risks as cost, system reliability, and integrated avionics development. The approved program called for 11 research and development (R&D) and 800 production aircraft. The full scale development contract for the airframe was awarded to McDonnell Douglas in January 1976 and the contract for the engine, to General Electric in November 1975. Initial operational capability (IOC) was scheduled for September 1982 but was actually completed in March 1983. Production began in November 1978. In December 1978, the Navy increased the production quantity from 800 to 1,366. In June 1981, the Secretary of Defense approved full production of the F/A-18 in its fighter role and directed implementation of cost-reduction initiatives, including a breakout of contractor-furnished equipment (CFE) to government furnished equipment (GFE), second-sourcing of major end items, and technology modernization. In December 1982, full production of the F/A-18 in its attack role was approved. In 1986, F/A-18 planned procurement was reduced to 1,157 aircraft. Production was scheduled for completion in FY 1995.

The F/A-18 has been substantially upgraded since its inception as a "low-cost" fighter. The first major upgrade of the F/A-18 occurred with the FY 1986 procurement (October 1987 delivery). The upgrade uses many subsystems developed as GFE systems by their sponsoring activities [E-1].

Table E-1 presents a summary of F/A-18 costs and schedule.

Table E-1. F/A-18 Program Data Summary

Program: F/A-18		**Service:** Navy	
Equipment: Naval strike fighter		**New/Modification:** New	
Year Dollars: 1975			

Milestone	Development Estimate (3/69)	Current Estimate (12/87)	Current Estimate for Development Estimate Quantity
Milestone II	12/75	12/75	12/75
Development Start Date	1/76	1/76	1/76
Development End Date (IOC)	9/82	3/83	3/83
Development Quantity	11	11	11
Development Cost	$1,437.7M	$1,652.3M	$1,652.3M
Milestone III (DSARC)			
Production Start Date	11/78	11/78	11/78
Last Production Aircraft Delivery	9/88	9/95	9/95
Production Quantity	800	1,157	1,157
Unit One Cost	–[a]	$73.8M	73.8M
Slope of Cost-Quantity Curve	–[a]	82.6	82.6
Production Cost	$6,560.9M	$12,403.6M	$9,311.9M
Total Program Cost	$8,016.0M[b]	$14,077.1M[b]	$10,964.2M
Years of Actual Data			
Development	9		
Production	10		

[a]Data not available.
[b]Includes military construction (MILCON).

According to the December 1976 Selected Acquisition Report (SAR), the F/A-18 program emphasized high reliability and maintainability (R&M) for lower operational and support (O&S) costs. Design-to-cost (DTC) was introduced as a requirement in the F/A-18 full scale development (FSD) contract. Multi-year procurement was considered as another cost-reduction effort, but it was rejected by Congress.

The prime contractors are McDonnell Douglas Aircraft (airframe), and General Electric (engine). The Northrop Corporation is a major subcontractor, producing the center and aft fuselage sections of the airframe.

2. Design-To-Cost Implementation

At McDonnell Douglas Aircraft (MCAIR), the F/A-18 DTC program was implemented through a program management system called MCAIR DTC in which Design

Engineering ran a cumulative record of the production cost of the air vehicle as drawings were released. Each design group received an allocation of labor and material cost, including CFE from the DTC goal. Design progress was measured by comparing the projected cost for released drawings to the value for that work in the DTC goal. The system was supported by the Engineering Producibility, Industrial Engineering, Production Planning, Procurement, and Fiscal divisions at MCAIR. Graphics were maintained on the project, and reports were circulated monthly to report status and cumulative progress. A provision for making trade studies at the life-cycle cost (LCC) level was also part of the system. Major equipment suppliers also had a DTC requirement in their purchase orders.

The MCAIR DTC allocation was based on the DTC estimate contained in the contract and related to the contract resources (the engines and central computer were government-furnished aircraft equipment).

According to some MCAIR personnel, a well-disciplined design team makes tradeoff studies and releases cost-effective drawings without the audit and documentation required for DTC. By the time the F/A-18 contract was definite, the airframe size, engine thrust, specific fuel consumption, avionics content, and armament were all well-defined by contract specification. Probability was low that DTC would have any more than a minor impact on flyaway cost.

3. Program Cost Summary

The cost summary of the F/A-18 program is given in Table E-1. Figure E-1 depicts the cost-quantity slope of the production program.

Compared with all tactical aircraft, the F/A-18 total program cost growth is 14 percent higher. The F/A-18 cost growth by program elements is shown in Table E-2.

As illustrated in Table E-2, F/A-18 development cost growth is 3 percent lower than that of all tactical aircraft programs, development schedule growth is 5 percent higher, development quantity growth is 10 percent lower, production cost growth is 17 percent higher, production schedule growth is 41 percent lower, and production quantity growth is 20 percent lower.

As of December 1987, F/A-18 program cost growth was estimated to be $2.7 billion or 36.6 percent in terms of base-year dollars adjusted for development estimate quantity (DEQ).

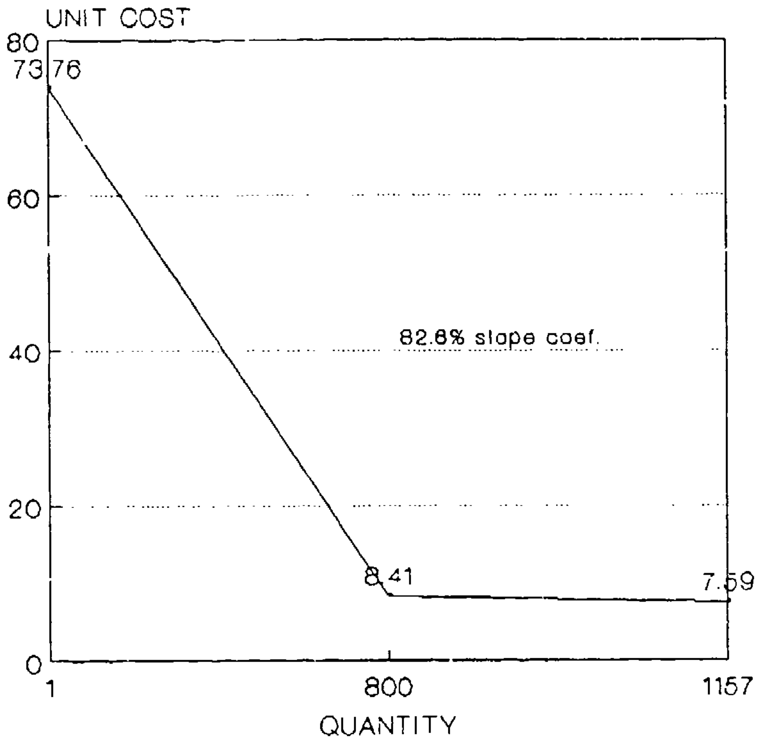

Figure E-1. F/A-18 Production Cost-Quantity Curve

Table E-2. F/A-18 Program Outcomes Versus All Tactical Aircraft

	F/A-18	All Tactical Aircraft
Development cost growth	1.15	1.18
Development schedule growth	1.08	1.03
Development quantity growth	1.00	1.10
Production cost growth	1.42	1.25
Production schedule growth	1.71	2.12
Production quantity growth	1.45	1.65
Total program cost growth	1.37	1.23

4. Analysis of DTC Goal Achievement

Based on the December 1987 SAR, the current estimate (CE) cumulative unit flyaway cost adjusted for DEQ obtained from the learning curve is $5.99 million versus the cumulative unit flyaway DTC goal of $5.6 million ($5.9 million threshold) approved when the program started in 1976. As of December 1987, the cumulative unit flyaway cost growth is $0.39 million or 7 percent over that of the approved DTC goal. But, if the threshold of the approved DTC goal of $5.9 million is considered, the current estimated cumulative unit flyaway obtained from the cost-quantity relationships study is only $0.1 million over the DTC threshold ($5.99 million versus $5.9 million). However, the average unit flyaway cost adjusted to the development quantity of 800 is $8.08 million compared with the $6.1 million estimated in 1976. So, if the average unit flyaway cost is considered instead of the cumulative unit flyaway, the unit cost growth is $.98 million or 32.5 percent, about 4.5 times higher than the cost growth of the cumulative unit flyaway cost. The summary of unit cost growth adjusted to development quantity based on cost-quantity relationships is depicted by Figure E-2.

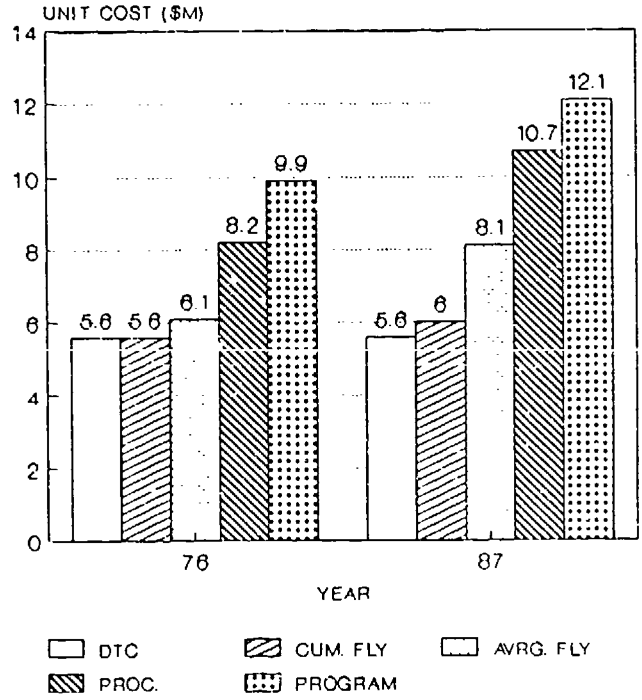

Figure E-2. F/A-18 Unit Cost Growth (In 1975 Dollars)

On a then-year dollar basis the total program cost growth (TPCG) reported in the December 1987 SAR is 189.4 percent. This figure includes the effects of inflation as estimated by the Office of the Secretary of Defense. The TPCG in base-year dollars adjusted for development estimate quantity is only 37 percent.

5. Findings

Since DTC was dropped from the program in 1978, specific conclusions on the effectiveness of the initiative for this program are difficult.

No DTC reporting has been performed at McDonnell Douglas since 1980. It appears that the contractor made a decision to meet only the NAVAIR specification performance requirements, believing that the Navy would not accept cost-reducing design changes that also affected system performance. DTC could be an effective initiative for a program, if applied properly, for the following reasons:

- DTC could have had a significant impact on the air vehicle if it had been implemented during the preliminary design or advanced design process, when airframe size, material content, engine thrust and specific fuel consumption, avionics, armament, fuel load, and payload would be subject to tradeoffs through the DTC approach.
- The use of advanced materials, higher thrust-to-weight ratios, improved specific fuel consumption miniaturization of electronic modules, etc., although seemingly higher in cost per pound, can significantly reduce gross weight, which can result in significant cost reductions associated with smaller air vehicle.

Measuring DTC success by relating DTC goals to firm proposals for initial production contracts will not help to identify the real design cost variance or the real causes for it. Schedules, worker skill levels and availability, timely introduction of firm drawings, available plant equipment, effective production planning, development changes, and stop work orders, all in combination with learning, have a significantly greater impact on initial production cost than does the design.

The following are observations about the F/A-18 DTC program from which lessons can be derived:

- The contractor did not perceive the Navy as being willing to trade other system parameters, e.g., performance for cost.
- The interrelationships of design, performance, and cost must be established during program development to allow cost-reducing design trades.
- In addition to establishing an overall DTC target, the contractor should identify cost drivers or establish and monitor specific cost goals at the components and subsystem level to assure control over DTC design changes.
- The original DTC goal must be continually updated and tracked through changes in design, performance, production quantity, and schedule.

- Parametric cost estimates must be updated to reflect actual costs as the data become available, because parametric cost estimates often vary widely from actual costs. This will permit an accurate and timely assessment of DTC program effectiveness.
- The contractor did not perceive the Navy as placing sufficient emphasis on DTC.
- The Navy perceived the contractor as appearing to make a sincere effort to implement the DTC program, but the contractor failed to follow it through.

B. AH-64A HELICOPTER

1. Program Description

The bulk of the information in this case study is from reference [E-4].

In September 1972, the Army approved the Advanced Attack Helicopter (AAH) System. The program called for nine RD&T aircraft and 536 production aircraft, which was later changed to 675. In June 1973, a two-phase development program was implemented. Phase 1 was a competitive development of two airframes, culminating in selection of the best airframe to enter Phase 2, full scale engineering development. Phase 2 focused on completing development of subsystems (missile, cannon, rocket, target acquisition, and night vision equipment) and their integration into the winning helicopter. Bell Helicopter Company and Hughes Helicopters were awarded contracts to design and fabricate a static test article, a ground test vehicle, and two flying prototypes to be evaluated in a competitive fly-off. Full scale engineering development contracts were awarded to Hughes on 10 December 1976. Although the contracts were awarded, they were to be modified to allow time for an Army-OSD Cost Analysis Improvement Group (CAIG) review of contractors' costs.

The Target Acquisition Designation Sight/Pilot Night Vision Sensor (TADS/PNVS) subsystems were subsequently directed for development as a competitive program, and contracts were awarded to Martin Marietta, Orlando, and Northrop Corporation on 10 March 1977. On 30 January 1981, the Army awarded a long-lead-time-items contract to Martin Marietta, Orlando, for the TADS/PNVS and on 20 February 1981, to Hughes for production AH-64s.

2. DTC Implementation

The AH-64 advanced attack helicopter (AAH) program has had DTC tracking from its outset. The AAH program began with a design-to-unit-production-cost goal of $1.4 million $1.6 million in FY 1972 dollars. This was later changed to a unit flyaway cost of $1.8 million in FY 1972 dollars. The original goal of $1.4 million to $1.6 million recurring cost per aircraft was based on the production cost for the A-10 airframe, an Air Force aircraft with a mission similar to the AAH (tank killer). OSD's rationale was that there no requirement existed for a second tank killer, considering that it would cost more than the existing weapon system.

3. Program Cost Summary

Table E-3 presents our analysis of the AH-64 program cost and schedule outcomes as compared to all helicopter programs in our database. The AH-64 development cost growth is only 26 percent compared to production cost growth of 74 percent. The total program cost growth is 59 percent. That is 20 percent higher then that of all helicopter programs in our study.

Table E-3. AH-64 Program Outcomes Versus All Helicopters

	AH-64	All Helicopters
Development cost growth	1.26	1.36
Development schedule growth	1.49	1.16
Development quantity growth	1.00	0.93
Production cost growth	1.74	1.46
Production schedule growth	1.02	1.01
Production quantity growth	1.26	0.95
Total program cost growth	1.59	1.39

4. Analysis of DTC Goal Achievement

With additions to the DTC goal to reflect definitive changes in DoD Instruction 5000.33 for flyaway costs; the impact of changes in mission equipment to include the Hellfire missiles and TADS/PNVS; adoption of the Armament Development Enfield/Direction D'Etudes et Fabrication D'Armament (ADEN/DEFA) 30mm round area weapon subsystem; changes in government-furnished equipment and changes in other system's programs (i.e., Blackhawk); the DTC goals had grown to $3.05 million in FY

1972 dollars by FY 1987. According to the December 1987 SAR, the latest approved DTC threshold is $3.31 million in FY 1972 dollars, or $10.66 million in then-year dollars. This suggests that DTC has been used more or less like a cost-monitoring device. The DTC goal was changed to adjust to the performance requirements of the system. More startling was the effect of escalation over the same period. Economic costs raised the AH-64 unit cost by $7.6 million to a total of $14.6 million in then-year dollars.

5. Findings

The primary value of the DTC program has proven to be the visibility and continuous record of costs it provides. DTC has not served to discipline cost growth, especially for non-recurring tooling, engineering, and program management service costs. It does provide the means to identify specific elements of cost growth.

Despite DTC, "the real" unit cost is not seen until a production proposal is received. The prime contractor is at the point where he must start to recognize some return on the investment (losses) made during a lengthy development. The AAH program management office, believing the program was tracking fairly close to the DTC goal, was shocked by Hughes' production proposal costs. Hughes had made several management personnel changes during the proposal preparation period and the new management had been directed to make a profit on the AAH program. The management office, however, was able to counter the new management's conservative approach to the perceived risks of moving into a new production facility through the use of detailed DTC recurring cost data.

DTC provides a database to evaluate and negotiate the contractor's production cost estimates. The data should be used to establish the government "business position" to the lowest reasonable cost.

The AH-64 DTC program was not fully executed. There was not enough manpower to conduct the in-depth analysis required.

The use of an award fee incentive on the achievement of DTC should not be expected to make DTC work. Neither Bell nor Hughes was awarded any of the award fees available for DTC issues in the first phase of the development. Hughes recognized by the second year of Phase II that it would never achieve the DTC goal and its award fee for all practical purposes was forfeit. Consequently, DTC was given lip service. Since Hughes was awarded the Phase II contract primarily on the basis of the technical merits of its aircraft despite known weaknesses in its management, the fact that it did not receive any of the fee for DTC is not surprising nor is it surprising that the AAH has proven to be more expensive than planned.

The TADS/PNVS DTC program has been relatively successful from its inception. Both competitors agreed to DTC goals that were as much as a third less than the Army's objective. Both contractors also paid attention to their DTC goals during their respective contractual performance. Although the actual DTC was greater than the contract goal, it was still less than the Army's objective. Contributing to the achievement of DTC were the use of competition for subcontracted parts to get reasonable prices, use of proven common night vision modules, and extensive use of automatic test equipment in production [E-4].

Lessons learned from the AH-64 DTC experience are listed below:

- A DTC program may not serve to discipline cost growth.
- Prototypes are necessary during engineering development (or advanced development).

REFERENCES

[E-1] F/A-18 Selected Acquisition Reports, March 1976, December 1976, and December 1987.

[E-2] Interviews with McDonnell Douglas personnel.

[E-3] AH-64A Selected Acquisition Report, December 1987.

[E-4] Defense Systems Management College, Department of Research and Information. "Lessons Learned: Advanced Attack Helicopter." Fort Belvoir, VA, July 1983.

Appendix F

TOTAL PACKAGE PROCUREMENT AND FIRM-FIXED-PRICE DEVELOPMENT CASE STUDIES

APPENDIX F
TOTAL PACKAGE PROCUREMENT AND FIRM-FIXED-PRICE DEVELOPMENT CASE STUDIES

A. C-5A AIRCRAFT

1. Program Description

The C-5A is an airlift aircraft designed to support material and manpower mobility. It has four General Electric TF-39 turbofan engines separately mounted under a 25-degree swept wing, high-flotation landing gear, and a truckbed-height cargo compartment with a straight-through loading/unloading capability. The mission of the C-5A is to provide a fast reaction capability to airlift combat and support units worldwide under general and limited war, as well as during peacetime.

The C-5A was the first program procured under the total package procurement (TPP) concept. The contract definition phase was initiated on 11 December 1964. In February 1965, DoD approved the TPP concept for the C-5A procurement. In October 1965, contracts were awarded to Lockheed for the airframe and General Electric for the engine. The IOC was set for December 1969 and was changed to June 1970 in early 1969, and accomplished on November 1970. Soon after Lockheed received the contract, it became apparent that the system was not well-defined. Both the Air Force and Lockheed knew that technical problems existed. These problems were further accentuated by the last-minute proposal to increase the surface area of the wing to meet takeoff and landing requirements. In 1968, concurrent with the technical difficulties, the program experienced large cost overruns (estimated at $200 million). In November 1969, the Air Force decreased its procurement quantity from 115 to 76 aircraft, which led to Lockheed's formal appeal in 1970. The dispute was settled in 1971 with a fixed loss of $200 million to Lockheed. Within four months after this settlement, two major C-5A wing test articles failed, conclusively demonstrating the existence of serious weaknesses. One wing broke before fulfilling the static strength requirements, while the other, in only 15,000 test hours, had cracked beyond effective repair. The last production aircraft was completed in

1973. The C-5A deficiencies study continued during 1973 and 1974. In 1975, the Air Force authorized a $1.6 billion C-5A wing-modification program. The contract was awarded to Lockheed on December 1975. Table F-1 presents a summary of the C-5A schedule from the September 1973 Selected Acquisition Report (SAR).

Table F-1. C-5A Program Data Summary

Program: C-5A — **Service:** Air Force
Equipment: Heavy logistics support system — **New/Modification:** New
Year Dollars: –[a]

Milestone	Development Estimate (12/69)	Current Estimate (9/73)	Current Estimate for Development Estimate Quantity
Milestone I			
Validation Contract Award	10/65	10/65	10/65
Milestone II			
Development Start Date	–[b]	–[b]	–[b]
Development End Date (IOC)	12/69	9/70	9/70
Development Quantity	5	5	
Development Cost	$1,041.8M	$1,025.6M	$1,025.6M
Milestone III (DSARC)			
Production Start Date	–[b]	–[b]	–[b]
Last Production Aircraft Delivery	4/72	5/73	5/73
Production Quantity	115	76	115
Unit One Cost	–[b]	–[b]	–[b]
Slope of Cost-Quantity Curve	–[b]	–[b]	–[b]
Production Cost	$2,327.8M	$3,527.1M	$5,337.5M
Total Program Cost[c]	$3,417.2M	$4,569.0M	$6,379.1M
Years of Actual Data			
Development –[b]			
Production –[b]			

[a]No base year indicated in the SAR. The 9/73 SAR indicated then-year dollars in the "Program Cost" section only.

[b]Data not available.

[c]Includes military construction (MILCON).

In keeping with the concept of total package procurement, the initial contract covered both development and production aircraft--5 research, development, test and evaluation (RDT&E) and 115 production aircraft (5 test aircraft, 53 aircraft (Run A), and the option for 57 additional aircraft (Run B)), along with a planning formula for another 85 aircraft (Run C). The Lockheed contract was a fixed-price-incentive-fee type, with a sharing ratio of 50/50 below target cost and 70/30 government/contractor sharing relationships above target. The contract target and ceiling costs totaled approximately $1.3 and $1.7 billion, respectively, for RDT&E and Run A. In January 1969, the Air Force decided to limit its procurement of the C-5A to 76 aircraft instead of 115 aircraft. The Run B option was exercised for only 23 aircraft. In November 1969, the Air Force notified Lockheed that the 23 aircraft would be the final buy. In 1970, Lockheed formally appealed the Air Force's decision to limit Run B. During this dispute, cost and technical problems continued. In January 1971, Lockheed accepted a settlement of $200 million fixed loss, and in May, the C-5A contract was amended to a cost-reimbursement with provisions for a fixed loss of $200 million.

DoD applied the TPP concept to the C-5A program acquisition in an attempt to prevent buy-in bidding, reduce cost overruns, instill greater competition throughout the acquisition process, and assign the contractor total responsibility for system design. This acquisition strategy attempted to integrate all development, production, and as much support as was practical into a single, fixed-price contract containing firm cost, schedule, and performance guarantees.

2. TPP Implementation

In December 1964, the Air Force released the C-5A request for proposals (RFP) to Boeing, McDonnell Douglas, and Lockheed. RFPs were also released to Pratt & Whitney and to General Electric for the engine. Each airframe company received notification that (1) contract award would be made to the source whose proposal demonstrated the greatest cost effectiveness over a 10-year period and (2) the system would have to comply with all minimum performance requirements. With the implementation of a TPP concept, the RFP not only had to specify performance and schedule requirements for supporting system development but also had to define operational and maintenance requirements so that the contractor could prepare life-cycle cost estimates. To maintain competition throughout source selection, each competitor signed firm, binding model contracts incorporating the performance and cost guarantees on which final selection was based.

Among numerous performance requirements, each airframe competitor guaranteed empty weight, payload, range, and takeoff and landing distances. The interrelationships of these specifications and the Air Force's demand for high performance forced the competitors to design all system elements near 100-percent effectiveness.

In August 1965, the Air Force selected General Electric to build the C-5A engines because its proposal was judged technically superior. In the same month, the C-5A source selection board recommended that Boeing be selected for the airframe contract since its design met all requirements, posed the least development risks, and offered the most cost-effective system. Lockheed offered the lowest target cost, but the board concluded that the company's design was unbalanced and contained takeoff and landing deficiencies. The board also believed that any Lockheed redesign to meet performance specifications increased schedule risk. The McDonnell Douglas proposal contained a series of performance deficiencies, and the necessary redesign created high schedule risk. The Air Force notified the contractors of the deficiencies in their proposals in September 1965, and the three airframe contractors submitted revised proposals three days later.

In the board's opinion, Boeing continued to meet all requirements and offered the most cost-effective program. While Lockheed's offer was approximately $300 million less than Boeing, their redesigned aircraft proposal (1) failed to meet one landing requirement, (2) added weight to an airframe that was already heavier than the others, (3) presented grave risks in meeting schedule requirements with a potential 6- to 12-month delay, and (4) raised the probability of target cost overruns. McDonnell Douglas's proposal improved its overall system cost effectiveness, but its design changes, like Lockheed's, included cost and schedule risks.

On 30 September 1965, Lockheed was selected for the airframe contract. The source selection authority, with the advice of 20 senior Air Force officers, considered Lockheed's proposal, including its lower acquisition cost and better loading and cargo-carrying flexibility, to be in the best interests of the government [F-2].

The C-5A contract contained an unprecedented provision for a $12,000 per day per aircraft penalty for late delivery according to a schedule that covered up to six years. There was a maximum limit of $11 million for the penalty. Upon contract award, Lockheed assumed full and associated risks for the design, development, production, and ultimate performance of the C-5A aircraft, including the integration of government-furnished jet engines manufactured by General Electric. The government, in a corresponding action, relaxed or eliminated certain program management controls practiced in previous procurements and began to follow a policy of "disengagement." By pursuing this policy, the C-5A program office increased Lockheed's freedoms to perform within the scope of the contract and refused to approve or to agree with contract changes that would have been perceived as limiting Lockheed's responsibilities.

3. Program Cost Summary

According to the C-5A SARs [F-1], the current estimate of the total C-5A program cost was $4.57 billion then-year dollars in 1973 versus $3.4 billion in 1969, including the Lockheed loss. Total program cost growth (TPCG) was $1.15 billion or 34 percent. Table F-1 presents the C-5A program cost and schedule summary as reflected in the first SAR (June 1969) through the last SAR (September 1973).

4. Analysis of TPP Goal Achievement

The C-5A did not achieve the performance, schedule or cost goals set forth in the contract. Airframe weight problems, which were known by the Air Force to exist in Lockheed's original design, led Lockheed to deviate from contract specifications by reducing wing material thicknesses. This action substantially reduced the aircraft's service life below the 30,000 flight hours desired. Lockheed's deviation from contractually required wing material thickness caused the problem with wings cracking being experienced today, which led to another 12-year C-5A wing modification program beginning in 1975. The cost of this modification program was estimated in 1974 as $896.3 million in then-year dollars and had increased to $1.55 billion by May 1981. Given that the Air Force authorized Lockheed to begin production before completing the development and testing phases, the full extent of the wing problem was not disclosed until 40 production aircraft had been accepted.

Lockheed's April 1965 response to the RFP appeared to be an adequately tested design that was optimized for cruise conditions, but unable to meet the strict takeoff and landing requirements. The contractor's attempt to remedy the requirements in just three days resulted in an unbalanced, untested design that developed severe weight and drag problems.

Control of the basic empty weight of the C-5A was a serious problem beginning early in the definition phase. The airframe weight grew from 302,495 pounds to 318,469 pounds at the time the contract was signed. The design changes that continued throughout 1966 compounded the problem. Several drag problems were solved by adding streamlining fairings, which always increase weight. In January 1967, Lockheed advised the Air Force that the C-5A performance requirements might not be met in full because of difficulties in achieving weight, lift, and drag targets needed for required performance. In February 1967, the Air Force notified Lockheed that its failure to meet the requirements constituted a condition endangering performance within the contract terms. In its attempts to fulfill the contract requirement for the empty weight of the airframe, Lockheed reduced wing material thicknesses below contract specifications [F-3].

Although the initial operational capability (IOC) was approved for a 6-month delay (June 1970), the C-5A program did not achieve IOC until 3 months later (September 1970). The last production aircraft was completed in May 1973 versus April 1972, a 13-month slip, even considering that the Air Force reduced the quantity [F-1].

The SAR shows TPCG of $1,155.8 million, or 34 percent, but this growth does not reflect the program quantity change. Adjusted for development estimate quantity (DEQ), the TPCG is $2,960.7 million or 87 percent. However, other factors also contributed to the C-5A cost growth. For example, engineering efforts required by Lockheed's aircraft design changes, Lockheed's underbid on subcontract costs, increased inflation rates above those predicted, and the buildup of the Vietnam War compounded cost increases by spawning a "seller's market," which forced subcontractor prices higher than anticipated and increased material lead times.

5. Findings

The TPP concept, as it was applied to the C-5A program, provided highly visible baselines for the program performance, schedule, and cost parameters. The attempt to establish firm obligations to be enforced up to 10 years later required that all program parameters be realistic and attainable. The C-5A program parameters were unrealistic at the time the contract was awarded. As a result, the program did not meet the required performance, schedule, and cost goals. The factors that led to an unsuccessful application of the TPP concept to the C-5A program are explained below:

- Contractor selection on price alone. Lockheed was selected on the basis of the lowest price, but its proposal was neither technically superior nor the most cost effective. The TPP did not require that the contract be awarded to the lowest bidder. Rather it required the award to be made to the competitor whose price and performance commitments were considered to be the most cost effective over the life of the system being procured.
- Performance and operational requirements. The Air Force's demand for certain aircraft performance and operational requirements forced the C-5A

contractors to achieve near 100-percent effectiveness in all system elements, leaving the contractors with little opportunity to make design tradeoffs.

- Concurrency. The imposition of an arbitrary initial IOC date that was not based on a realistic acquisition strategy or governed by the contractor's ability to perform and which forced the Air Force to authorize Lockheed to begin production before completing the development and testing phases.
- Poorly planned definition phase. Fundamental to the TPP concept was a thorough definition phase. The most significant error in the C-5A program was the apparent disregard for the major products of the definition phase. The 9-month effort was replaced by a hastily redesigned proposal.
- Underestimation of technical requirements. System planners made the incorrect assumption that the C-5A was nothing more than a larger version of the C-141.
- Inadequately defined management procedures and contract standards.

Because of these problems, the TPP concept was an unsuitable acquisition strategy for the C-5A. However, the TPP concept, corrected for some obvious mistakes stated above, and applied to a reasonably well-defined system, could still be a useful tool for weapon system acquisition.

Although the C-5A was procured under a TPP contract, some of the decisions and events in the program should be highlighted. The use of fixed-price contracting and government noninterference during the development phase of a major system such as C-5A results in loss of flexibility both to the government and to the contractor. This, in turn, leads to interrelated problems affecting the cost, schedule, and performance of this aircraft. Lessons to be learned from the C-5A total package procurement program are:

- Contracting is an important tool of system acquisition, it is not a substitute for managing acquisition programs.
- The procurement activity should weigh the risks of selecting the contractor with the lowest acquisition or life-cycle cost. If a selected contractor's proposal contains unrealistic cost, schedule, and performance optimism or guarantees, the cost of acquiring that system can eventually become excessive.
- Both the procuring activity and contractor must take mutual responsibility to revise and renegotiate the selected acquisition strategies when they are unsuitable for a given problem. The contractor must not be depended upon totally to identify problems in new systems under development, which might affect the safety and integrity of the system.

- When a contractor plans to deviate from contract specifications that jeopardize system safety, service life, or other performance characteristics, the contractor and the procuring activity have a joint responsibility for (1) verifying the potential impact of the change and (2) taking whatever action is appropriate for preserving system integrity before proceeding with the planned change.
- Concurrency increases the risks of costly modifications to obtain desired performance characteristics. While concurrency may speed the acquisition process, its use can prevent the disclosure of design deficiencies or other problems until substantial amounts of production hardware have been accepted. The use of concurrency should be limited to those system acquisitions whose technology is at hand or whose urgent military need has been validated.
- Contract practices should foster government-contractor relationships, which would encourage both parties to work together to achieve the most cost-effective approach to satisfying the mission needs.

B. MAVERICK MISSILE

1. Program Description

The Maverick is a TV-guided, rocket-propelled, air-to-surface missile designed to destroy visible, small, hard tactical targets in the counter-air, interdiction, and close-air-support operations of tactical air forces. It is capable of being carried externally throughout the mission profiles of the F-4D/E, A-7D and A-10 aircraft. The Maverick AGM-65A is restricted to daylight operations. This version was followed by versions B, D, F, and G, which currently are ongoing programs. U.S. procurement of the A and B models is completed with a total production run of over 30,000 missiles, but foreign military sales continue.

The request for proposals (RFP) for the Contract Definition Phase (CDP) was issued in July 1966. The prime contractor was Hughes Aircraft Corporation. The program development estimate called for 205 RDT&E and 17,000 production missiles, which were changed later to 186 and 20,100 missiles, respectively. Development of total package procurement (TPP) was initiated in July 1968. The IOC was achieved in February 1973 and production of the AGM-65A started on July 1971, and was completed in May 1976 [F-4]. Test firings were completed on or ahead of schedule, with a success rate of 91 percent versus a requirement of 80 percent. All other major performance parameters were met or exceeded. Success rates in training and combat were 92.2 and 88 percent, respectively. The total program was completed at 5.1 percent over the target price [F-5].

The Maverick AGM-65A's TPP program was initiated when many, if not all, such programs were encountering major problems. As a result, the CDP was extended about a year to allow intensive face-to-face negotiations on all aspects of the contract. From both the government's and the contractor's viewpoints every effort was made to anticipate contingencies and loopholes and to design "the perfect contract."

The contract with Hughes is a fixed-price TPP contract. Cost, schedule, and performance incentives are 50/50 under target, 70/30 over, and up to 125 percent of target cost. Contractually, the program contained a system full scale development phase (missile, launcher, and support and handling equipment) and three options for a total of 17,000 missiles as well as launchers and support and handling equipment.

Table F-2 presents a summary of Maverick's costs and schedules.

Two important contractual features led to the success of the Maverick AGM-65A's total package procurement:

- Two-way incentives with awards for good performance and penalties for unacceptable performance. For example, missile hit rate success required 90 percent performance for a $3 million incentive. The incentive was scaled to zero at an 80-percent performance level and scaled to a $1.5 million penalty at the 70-percent level. Below 70 percent required the contractor to build, at his own expense, replacement hardware for additional testing.
- Escalation clause. The 1970s was an era of high inflation, and without the escalation clause, the contractor would have lost millions of dollars [F-5].

2. TPP Implementation

The Maverick TPP contract was heavily influenced by the political environment during the contract definition phase. The failure of other TPP programs (i.e., C-5A and SRAM) led the government to tighten the contract's terms and conditions by steepening share patterns, lowering the ceiling, and favoring a fixed-price type of contract. In addition, the uncertainties of the U.S. economy -- inflation, negative balance of payments, and a weakening of the government's will to maintain the wage guidelines -- were becoming apparent. The negative public attitude toward the war in Vietnam added to the conflict between defense spending and the funding of social programs.

Table F-2. Maverick Program Data Summary

Program: AGM-65A Maverick	**Service:** Air Force
Equipment: Air-to surface tactical missile	**New/Modification:** New
Year Dollars: 1968	

Milestone	Development Estimate (12/69)	Current Estimate (9/76)	Current Estimate for Development Estimate Quantity
Milestone I			
Contract Award	7/68	7/68	7/68
Milestone II			
Development Start Date	7/68	7/68	7/68
Development End Date (IOC)	12/71	2/73	2/73
Development Quantity	205	186	205
Development Cost	$115.7M	$120.7M	$133.0M
Milestone III (DSARC)			
Production Start Date	7/71	7/71	7/71
Production End Date	–[a]	–[a]	5/73
Production Quantity	17,000	20,100	17,000
Unit One Cost	–[a]	$.04M	$.04M
Slope of Cost-Quantity Curve	–[a]	90.4	90.4
Production Cost	$215.0M	$245.6M	$179.93M
Total Program Cost[b]	$330.7M	$366.3M	$312.93M
Years of Actual Data			
Development Completed			
Production Completed			

[a]Data not available.

[b]Does not include military construction (MILCON).

Four "Milestone Requirements" or "Fly Before Buy" criteria were imposed:

- 21 successful target simulation tests prior to Category I flight tests.
- 3 specification launches at envelop extremes prior to Category II tests.
- 5 successful launches prior to production go-ahead.
- Category II tests conducted by the Air Force to specification.

In addition, a success record of 35 out of 40 in Category II tests would win a $3 million incentive, a record of 29 out of 40 would require a $1 million penalty, and less than 29 successes would require a redesign by Hughes and a repeat of the Category II tests without adjustment of target cost or ceiling.

If the milestone requirements were not passed on schedule, then the contractor was to proceed until they were passed. As a result, Hughes devoted a lot of time negotiating Section 4 of the specifications relative to CAT II test conditions. It also negotiated a clause in the contract for a Unique Reliability Test (URT) Program, which was analogous to the Test, Analysis, and Fix concepts later conceived by NAVAIR and now being included in Navy programs [F-5].

Cost management was based on holding the program schedule and performance goals with a plan created by Cost Schedule Planning and Control. Expenditures were between $3 million and $4 million per month. The program was completed on schedule and on budget. The reporting included daily telephone calls and a weekly report on the program status. The Air Force Program Officer was also invited to attend Hughes's weekly staff meetings.

Hughes's design concept encompassed the following:

- Design for production by all parties from the start of CDP through development.
- Cost targets and a responsible engineer for each major subsystem were established during CDP and were monitored during DT&E.
- Well-known technology was used unless a need for a more inventive methodology was found to be mandatory.
- Risk areas determined early in the CDP were subjected to critical investigation and test with Hughes money prior to DT&E.
- The URT Program was implemented to avoid the dip in reliability between Categories I and II and production. The Category I flight test program was laid out so that problems could be determined early (i.e., the worst case test was conducted early in the test program) and corrected without stretching Category I.
- A Value Engineering (VE) clause was included in the contract. The Maverick clause was unique at the time in that there were no instant savings to the contractor. No change in target or ceiling price due to approval of a Value Engineering Change Proposal was made. Cost sharing was in accordance with the contract cost share pattern and was based on total contract performance.

Three types of risks were considered by the contractor: financial risk, technical risk, and business risk.

Financial risk was spread by careful selection of proven subcontractors for major subsystems. Each major subcontractor was offered an economic escalation clause.

Technical risks were carefully assessed during the CDP. Hughes handled this by initiating tests and established contractual provisions, such as the URT and VE clauses. During CDP, Hughes initiated contracts with McDonnell Douglas, LTV, and General Dynamics for wind-tunnel tests of the multiple-rail launcher. Interface specifications and interface working agreements were negotiated to solve what otherwise would have caused formidable problems in timing, schedule, and cost.

The fallout of unknown risks was solved by technical or value engineering solutions without significant compromise to the operational requirements.

The business risk perceived in the CDP was bankruptcy due to lack of a proven production design. Hughes tried to minimize this threat by spreading the risk, making extensive use of major subcontractors. However, the business risk encountered with suppliers during the course of the contract was far greater than Hughes anticipated. The war time versus non-war time business environment was not anticipated. The change in sales, and hence in their operating base, was a critical and sometimes fatal problem to Hughes' suppliers. There was no apparent good solution to this problem.

3. Program Cost Summary

According to the September 1976 SAR [F-1], the current estimate of the total program cost in 1976 was $366.3 million versus the development estimate of $330.7 million in 1968. This represents a cost growth of $35.6 million or 10.8 percent. This cost growth included both the RDT&E quantity decrease of 19 and the procurement quantity increase of 3,100 missiles. In 1968 base-year dollars, the program development cost adjusted for DEQ increases about $17.3 million or 15 percent, but the procurement cost adjusted for DEQ decreases about $35.1 million or 16.3 percent. The TPC adjusted for DEQ reflects a decrease of $17.8 million or 5.4 percent. Table F-2 shows the program cost summary as reflected in the SARs.

4. Analysis of TPP Goal Achievement

According to Hughes, the overall schedule was met to within 1.1 percent. This performance was achieved by hard work, dedicated personnel, good management, and minimal external distraction (because Hughes did not have to propose and negotiate a new contract every year, the environment was stable). Acceptance of good VE proposals by the Air Force also contributed significantly to the program's schedule performance.

The Categories I and II flight test programs and ground tests of the warhead showed that the Maverick AGM-65A equalled or exceeded all the major requirements. The mission success rate was 13/16 in Category I and 27/28 in Category II for an overall rate of 91 percent versus the 80 percent required. Carrying three missiles per assigned airframe, hardpoint was achieved on both the A-7 and F-4 aircraft. Warhead penetration was substantially better than the requirements. The Maverick success rate has held up well after Categories I and II, including an impressive 88 percent success in combat and 92 percent success in training and demonstration firings.

The cost performance for the Maverick was just as impressive as the schedule and technical performance. According to Hughes, the total program was within 5.1 percent over target cost, and program continuity was a major factor contributing to this success. The original target cost increased from $323.2 million to $418.6 million, of which $78.7 million was due to economic escalation and $16.7 million for scope changes. Hughes received maximum performance incentives of $3 million and $5 million for the Category II and operational incentives, respectively [F-5]. We do not know what definition of cost growth Hughes used. According to our analysis of the SARs, the Maverick AGM-56A/B had no cost growth. The total program cost (excluding military construction) was about 5.4 percent lower than the development estimate.

5. Findings

One of the major advantages of TPP from the contractor's viewpoint is that once having defined the contract in CDP, the contractor is free to proceed with the development with a minimum of outside review. Thus, Hughes controlled Category I, and the Air Force monitored for compliance with the milestone and other requirements in the contract terms. This is a big plus when key managers can work towards meeting the contract requirements in lieu of spending a significant amount of their time preparing for monthly, bi-monthly, or quarterly reviews.

The Maverick program could not have been accomplished without successful application of the VE clause. Of 143 VE change proposals submitted, 90 were approved. No significant compromises in operational capability were made. In fact, the performance is substantially better than required in many critical areas. VE savings in development and production totaled $29.2 million, with an additional savings of $10.7 million anticipated in the cost of ownership. Hughes and the Maverick System Program Office (SPO) received the 1971 Aeronautical Systems Division VE award. Rigid adherence to the specifications and contract and rejection of value engineering changes were major contributing factors to the C-5A overrun [F-5].

Another unique clause provided for an operational firing incentive. Success or failure was determined by counting the hits versus the misses. The Air Force was judge and jury.

Program continuity was a major factor contributing to the Maverick TPP success. From initiation of the CDP through the initial phase of the third option, the program and fiscal continuity permitted the following:

- Program manpower during CDP peaked at about 300, then dropped to about 40 during negotiation.
- Subsequent to the start of DT&E, there were no interruptions for decisions -- program manpower was maintained as required to get the job done.
- Manpower during production did not radically increase, going from the first to second to third options even as the peak missile production rates in the options went from about 275 to 550 to 850 per month.
- The percentage of support for management and engineering declined from 17.4 to 7.6 between the first and third option.
- Long-lead time (LLT) money for the second and third options was included in option one, and additional LLT money for option 3 was included in option two.

If Hughes had not been tied to a total package procurement, the Air Force would have stabilized at the first option production rate with a cost increase of 25-30 percent without consideration of inflation [F-5].

A number of lessons can be learned from the success of the Maverick program:

- Program continuity provides major payoffs. Sequential decision-making without funding and manpower continuity would be an assured way of increasing cost and guaranteeing overruns.
- A fully integrated service SPO, including management, engineering, contracts, finance, operations, and support, permits decisive, timely programmatic decisions.
- Modest expenditures at the beginning of a program to define and investigate potential problems prevents later schedule slippage and major expenditures.

- Careful selection and application of known technology that is appropriate to the real need in lieu of high-risk technology is a major key to predictable performance, schedule, and cost.
- A production design, backed by system analysis, simulation and critical subsystem testing, in conjunction with a reasonably detailed Cost, Schedule, Planning, and Control program plan and extensive face-to-face negotiations, provides the basis for good source selection without the cost in time and money for full-scale system flyoffs.
- A method, such as the Maverick VE program, for the expeditious treatment by the government and the contractor of unnecessary and costly contractual and technical requirements is essential.
- The selection of options for production rates yields large unit-cost savings.
- Finally, sound engineering, good personnel, strong management, and a contract that thoroughly defines responsibility and authority can achieve impressive results.

C. V-22 AIRCRAFT

1. Program Description

The V-22 Osprey is a Navy program for the purpose of developing, testing, evaluating, procuring, and fielding a tilt-rotor, vertical/short takeoff and landing (V/STOL) aircraft for joint-service application. The V-22 is designed to meet the amphibious/vertical assault needs of the Marine Corps, the combat search and rescue needs of the Navy, and the special operations needs of the Air Force. The integration of three relatively new technologies (tilt rotors, an all-composite airframe, and fly-by-wire digital controls) makes the V-22 program one of the "highest tech" of all aviation acquisition programs. The V-22 will be capable of flying over 2,000 nautical miles without refueling, giving the Services the advantage of a V/STOL aircraft that can rapidly self-deploy to any location in the world. As a hybrid helicopter/fixed-wing transport aircraft, the Osprey will be capable of taking off and landing in confined areas in its helicopter mode and transforming to high-speed, fuel-efficient flight in its airplane mode. The V-22 will have the capability to insert combat power into previously impossible-to-reach regions, thus providing the U.S. with new dimensions in military power [F-6].

The V-22 preliminary design was initiated in April 1983 with Bell Helicopter Textron and Boeing Vertol. Allison Gas Turbine Division of General Motors Corporation was selected for engine design. In April 1986, the V-22 program was approved for entry into full scale development (FSD). A fixed-price FSD contract was awarded to Bell-Boeing as joint contractors on 1 May 1986. The IOC date is scheduled for fiscal year 1995. Production of the actual aircraft will begin in 1989 and deliveries are scheduled for the Marine Corps in 1991 and for the Navy and Air Force in 1994. Table F-3 presents the V-22 program cost and schedule summary as reflected in the SARs. The system is still fairly new and has not had a lot of time to accumulate cost growth.

Table F-3. V-22 Program Data Summary

Program: V-22
Equipment: Joint-service, advanced vertical-lift aircraft
Year Dollars: 1986[a]
Service: Marine Corps, Navy, Air Force
New/Modification: New

Milestone	Development Estimate (12/83)	Current Estimate (12/87)	Current Estimate for Development Estimate Quantity
Milestone I	12/82	12/82	12/82
Preliminary Design Contract Award	4/83	4/83	4/83
Milestone II	4/86	4/86	4/86
Development Start Date	5/86	5/86	5/86
Development End Date (IOC)[b]	FY 1992	FY 1994	FY 1994
Development Quantity	6	6	6
Development Cost	$2,443.7M	$2,471.4M	$2,430.9M
Milestone III (DSARC)			
Production Start Date[c]	12/89	12/89	12/89
Production End Date	FY 1997	FY 1999	FY 1999
Production Quantity	913	682	913
Unit One Cost	_[d]	_[d]	_[d]
Slope of Cost-Quantity Curve	_[d]	_[d]	_[d]
Production Cost	$20,493.1M	$15,911.3M	$19,143.1M
Total Program Cost[e]	$23,073.0M	$18,518.8M	$21,574.0M
Years of Actual Data			
Development	6		
Production	0		

[a]Adjustment from FY 1984 to FY 1986 in 12/86 SAR.

[b]The first IOC date (IOCs are different for the three services).

[c]Pilot production date (milestone IIIA).

[d]Data not available.

[e]Includes military construction (MILCON), initial spares, and other weapon system costs.

The program calls for 6 RDT&E and 913 production aircraft. Presently in its FSD phase, the V-22 program is experiencing some engineering problems, which could degrade its operational effectiveness and safety. These include: (1) fuselage crashworthiness, (2) crew seat design, (3) fuel cell burst characteristics, (4) prop-rotor blade impact, (5) engine heat, (6) lead-acid battery, (7) weather radar, (8) throttle quadrant, and (9) wire-strike protection [F-7].

2. FPD Contract Implementation

The Navy has adopted a firm-fixed-price (FFP) contract strategy from FSD through production. Fixed-price contracts are good for controlling systems with few unknowns and low risks because these contracts can curtail high production costs. However, for the V-22, a system whose three new technologies have many unknowns and high risks, a long-term fixed-price contract strategy for procuring several hundred aircraft through the 1990s may not be an efficient acquisition tool.

The Bell-Boeing contract is a $1.8 billion contract. It calls for producing components of 11 equivalent aircraft, a ground test vehicle, six test-flight aircraft, and the major assemblies for tooling, structural testing, and ballistic testing. Once completed, these tooling assemblies will lock the V-22 design for several hundred aircraft in "concrete." The Marines are committed to purchase 552 Ospreys; the Navy, 50; and the Air Force, 80. The Army cancelled its original commitment to buy 231 in mid-January 1988, which reduced the production quantity from 913 to 682. The V-22 program manager plans to offset the Army loss with foreign military sales of 500 to 600 Ospreys. The Allison Gas Turbine contract is a $76.4 million FFP contract. The contract for the aircraft and the acquisition strategy do not contain any provisions for making major changes in the production line. Aside from making minor configuration changes, the strategy was not constructed to incorporate major development test and operational test (DT/OT) "findings" or new engineering research into the V-22's production. There are no plans for block improvements.

3. Program Cost Summary

According to the SARs, the CE of the total program cost (TPC) was $18.52 billion in 1987 versus $23.1 billion 1986 base-year dollars in 1984. Due to the reduction in production quantity, the CE of TPC decreased approximately $4.6 billion. However, the CE of TPC adjusted for DEQ is $21.57 billion, reflecting a decrease of only $1.5 billion or 6.5 percent. The system is still fairly new and has not had much time to accumulate cost experience.

4. Analysis of FPD Goal Achievement

The acquisition strategy and new technologies contained in the V-22 program could involve risks which are too high for the government, the contractor, or both. With the application of a firm-fixed-price contract, the operational effectiveness and safety of the V-22 could be degraded by engineering problems, which in turn could lead to cost increases and schedule delays.

The V-22's performance characteristics and mission scenarios may not be achieved due to potential engineering problems that fall into two categories: crashworthiness problems and configuration issues.

The fuselage crashworthiness problems are directly related to the V-22 program's fixed-price contract. The Osprey's fuselage crashworthiness standards have been continually reduced from its original MIL-STD 1290 specification. This is because the contractors were not willing to assume the risks and costs of achieving higher levels of crashworthiness under the constraints of a fixed-price contract. As a result of a modification to the Navy standard for crashworthiness, the contractor is authorized to meet MIL-STD 1290 to the "maximum extent practical" rather than to comply strictly with the standard. If the flexibility of a cost-plus contract had been given, Bell and Boeing would have been willing to work toward higher levels of crashworthiness. The other crashworthiness problems and the configuration issues are indirectly related to the fixed-price contract in the sense that they could have been eliminated with additional monies. But the issues were not considered during the contract negotiation process.

The System Safety Working Group (SSWG) No. 8 briefing on the V-22 exhaust profile predicted an excessive engine temperature of 575 degrees F, which makes the aircraft unsuitable for landing safely and hovering in unimproved sites where vegetation or combustible materials exist. In SSWG No. 9 , the contractor predicted much lower engine heats and stated that the new heat levels would not be a safety factor in these situations. However, detailed tests of the V-22 exhaust plume should be conducted to accurately evaluate its heat profile. If the aircraft's temperatures are excessive, the V-22's forward looking infrared (FLIR) system and all standard aviation night vision goggle devices could be ineffective.

Since the V-22 is still in the development phase, the CE does not indicate any schedule slip due to firm-fixed-price acquisition strategy.

The program experienced only a slight increase ($27.7 million 1986 dollars or 1.1 percent) in program RDT&E. Due to production quantity change, the CE of procurement cost decreased by $4,581.8 million. The CE of production cost adjusted for DEQ ($19,143.1M) also shows a decrease of $1,350.0 million or 6.6 percent. The TPC adjusted for DEQ shows a slightly smaller decrease (6.5 percent) [F-7].

5. Findings

Although a long-term, fixed-price contract can cut runaway acquisition costs during production, a firm-fixed-price strategy from FSD through production for procuring several hundred V-22s through the 1990s is not a good acquisition strategy for the critical multi-service, "high tech" V-22 program. With simultaneous implementation of three new technologies (all-composite airframe, fly-by-wire controls, and tilt rotors), the V-22 program would most likely be exposed to much higher risks than those of other major acquisition programs. Four constraints in the program acquisition strategy reduce the program's ability to contend with the V-22's technological risks and unknowns:

- The contractor's costs for integrating the V-22's new technologies into the program could be too high or too low with respect to the value of the contract.
- Neither the contractor nor the government may have a good appreciation of the program's actual risks.
- The contractor could be charging the government for assuming these risks.
- There are no clauses within the development contract for taking advantage of DT/OT "findings" or engineering research that pertains to the V-22's three new technologies. There are no provisions for incorporating DT/OT findings or engineering research pertaining to the V-22's new technologies into the V-22 production line.

Considering the number of V-22 technical unknowns that could be resolved by engineering research and DT/OT findings, a firm-fixed-price FSD contract adopted for the program may not be appropriate. A firm-fixed-price contract may be appropriate if one of the following conditions exists:

- An historical price comparison can be made
- Available cost or pricing data permit realistic estimates of probable performance costs
- Contract performance uncertainties can be so clearly identified that their impact on price can be evaluated.

When none of these conditions exists, the use of a fixed-price contract with an incentive feature, or a cost-reimbursement type of contract, is normally considered more appropriate. In the case of the V-22 program, the fixed-price contract adopted should be expanded and refined as the program progresses to give the program flexibility, which is of foremost importance in controlling the cost of engineering design changes.

REFERENCES

[F-1] C-5A Selected Acquisition Reports, June 1969, December 1969, December 1970, December 1971, December 1972, and September 1973.

[F-2] Poncar, Jerry V., and James R. Johnston II. *History and Analysis of the C-5A Program: An Application of the Total Package Procurement Concept.* October 1970.

[F-3] Comptroller General's Report to the Vice Chairman, Subcommittee on International Trade, Finance and Security Economics, Joint Economic Committee. *C-5A Wing Modification: A Case Study Illustrating Problems in the Defense Weapons Acquisition Process.* 22 March 1982.

[F-4] Maverick AGM-65A Selected Acquisition Reports, June 1969, December 1969, December 1970, December 1971, December 1972, December 1973, December 1974, December 1975, and September 1976.

[F-5] Hughes Aircraft Corporation. "Case Study of the Maverick AGM-65A Total-Package Procurement Success."

[F-6] Beacon, Alan J. "The V-22 Program's Need for A More Flexible and Farsighted Acquisition Strategy." Air Command and Staff College, Report No. 88-0145, April 1988.

[F-7] V-22 Selected Acquisition Reports, December 1984, December 1985, December 1986, and December 1987.

ABBREVIATIONS

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AAH	advanced attack helicopter
ADDS	Army Data Distribution System
ADEN/DEFA	Armament Development Enfield/Direction D'Etudes et Fabrication D'Armament
ALCM	Air-Launched Cruise Missile
AMRAAM	Advanced Medium-Range Air-to-Air Missile
APSI	aircraft propulsion system integration
ASPJ	Airborne Self-Protection Jammer
ATEGG	advanced turbine engine gas generator
CAE	Carrier Aircraft Equipment
CAIG	Cost Analysis Improvement Group
CCDR	Contractor Cost Data Reporting
CDP	Contract Definition Phase
CE	current estimate
CFE	contractor-furnished equipment
CIP	Component Improvement Program
CLGP	Cannon-Launched Guided Projectile
CPFF	cost plus fixed fee
CPIF	cost plus incentive fee
DAB	Defense Acquisition Board
DAE	Defense Acquisition Executive
DCA	Defense Communications Agency
DCG	development cost growth
DCP	Development Concept Paper
DDR&E	Director of Defense Research and Engineering
DE	development estimate
DEQ	development estimate quantity
DMS	Defense Marketing Service
DMSP	Defense Meteorological Support Program
DoD	Department of Defense
DQG	development quantity growth
DRB	Defense Resources Board
DSARC	Defense Systems Acquisition Review Council
DSCS	Defense Satellite Communications System

DSG	development schedule growth
DSMC	Defense Systems Management College
DSP	Defense Satellite Program
DT&E	development test and evaluation
DT/OT	development test and operational test
DTC	design-to-cost
FFP	firm-fixed-price
FLIR	forward-looking infrared
FMS	foreign military sales
FPD	fixed-price development
FSD	full scale development
FYDP	Five-Year Defense Plan
GAO	General Accounting Office
GD	General Dynamics
G.E.	General Electric
GFE	government-furnished equipment
GLCM	Ground-Launched Cruise Missile
GNP	gross national product
GP	guided projectile
GPS	Global Positioning System
HARM	High-Speed Anti-Radiation Missile
ICBM	intercontinental ballistic missile
IMP	improved
IOC	initial operational capability
IOT&E	initial operational test and evaluation
JCMPO	Joint Cruise Missile Program Office
JSTARS	Joint Surveillance and Target Attack Radar System
JTIDS	Joint Tactical Information Distribution System
LAMPS	Light Airborne Multi-Purpose System
LANTIRN	Low-Altitude Navigation and Targeting Infrared System for Navigation
LCC	life-cycle cost
LLT	long-lead time
LTV	Ling-Tempco-Vought
MCAIR	McDonnell Douglas Aircraft
MILCON	military construction
MLRS	Multiple-Launch Rocket System
MSIP	Multi-Staged Improvement Plan
MYP	multi-year procurement
NAVAIR	Naval Air Systems Command

NCA	Naval Center for Cost Analysis
O&S	operational and support
OFPP	Office of Federal Procurement Policy
OSD	Office of the Secretary of Defense
OTH-B	Over-the-Horizon Backscatter
P&W	Pratt & Whitney
PCG	production cost growth
POST	passive Optical Seeker Technique
PPBS	Planning, Programming, and Budgeting System
PQG	production quantity growth
PSG	production schedule growth
R&D	research and development
R&M	reliability and maintainability
RD&T	research, development, and test
RDT&E	research, development, test, and evaluation
RFP	request for proposals
RMP	Reprogrammable Microprocessor
SAL	Semi-Active Laser
SAR	Selected Acquisition Report
SDDM	Secretary of Defense Decision Memorandum
SINCGARS	Single Channel Ground and Airborne Radio System
SLCM	Sea-Launched Cruise Missile
SPO	System Program Office
SRAM	Short-Range Attack Missile
SSWG	System Safety Working Group
STD MSL	Standard missile
TADS/PVNS	Target Acquisition Designation Sight/Pilot Night Vision Sensor
TI	Texas Instruments
TOA	total obligational authority
TOW	tube-launched, optically tracked, wire-guided
TPC	total program cost
TPCG	total program cost growth
TPP	total package procurement
TRI-TAC	Joint Tactical Communications Office
UER	unscheduled engine removal
URT	Unique Reliability Test
USDRE	Under Secretary of Defense for Defense Research and Engineering
UTTAS	Utility Tactical Transport Aircraft System
V/STOL	vertical/short takeoff and landing

VE	Value Engineering
WIS	World Wide Military Command and Control Information System